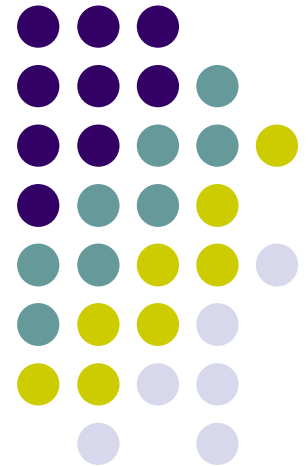
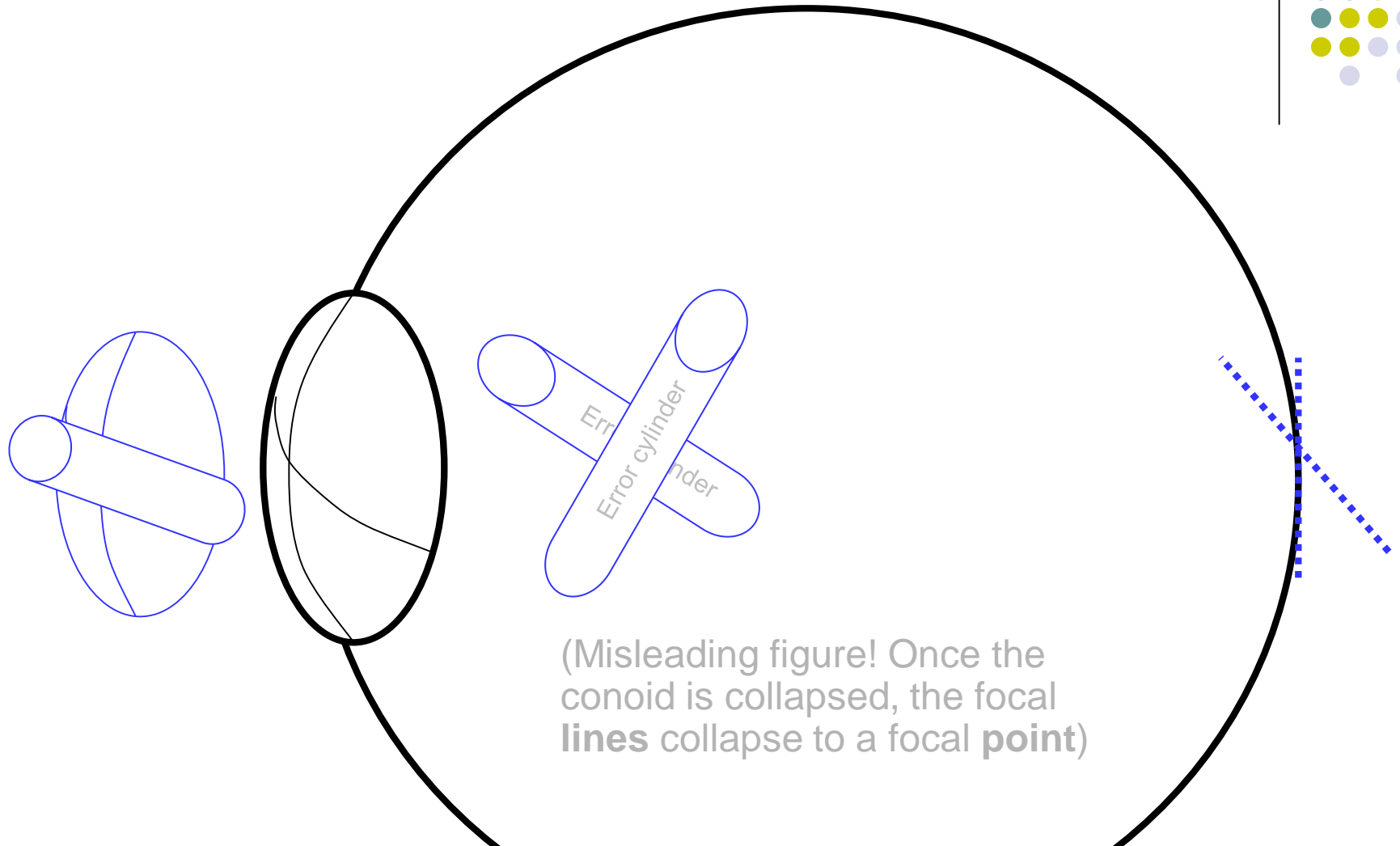
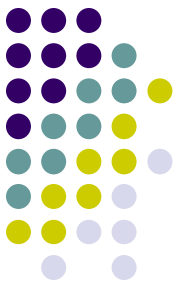


Astigmatic Refractive Correction: *Jackson Cross*

Basic Optics, Chapter 13

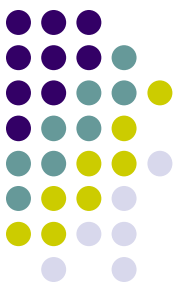


Astigmatic Eye Error



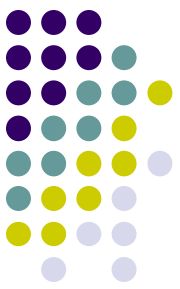
In Chapter 11, we saw that astigmatic refractive error results from two cylindrical error lenses, and therefore requires a spherocylindrical lens for its correction.

Astigmatic Correction



- There are two commonly-used clinical techniques for refracting the astigmatic patient:
 - *Retinoscopic*
 - *Jackson Cross*

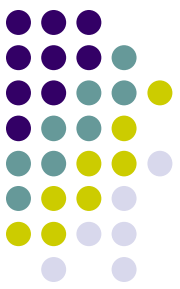
Astigmatic Correction



- In Chapter 12 we saw how retinoscopic astigmatic refraction works. Now we will turn our attention to the **Jackson Cross** approach.

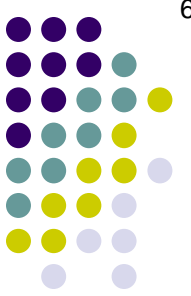
| | <i>Retinoscopic</i> | <i>Jackson Cross</i> |
|---------------|---|---|
| <i>Step 1</i> | Use sphere to place one focal line on the retina | ? |
| <i>Step 2</i> | Use cylinder to place the other focal line on the retina | ? |
| <i>Result</i> | Conoid collapsed to a point on the retina | Conoid collapsed to a point on the retina |

Astigmatic Correction: *Jackson Cross*



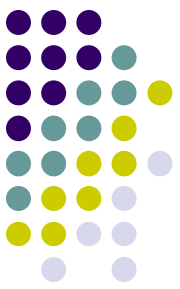
- In the *Jackson Cross* approach, the focal lines are attacked *simultaneously*
 - **First**, sphere is used to place the Circle of Least Confusion on the retina

Astigmatic Correction: *Jackson Cross*



- In the *Jackson Cross* approach, the focal lines are attacked *simultaneously*
 - **First**, sphere is used to place the Circle of Least Confusion on the retina
 - **Then**, the Jackson cross cylinder is used to...
 - 1) identify the axis of astigmatism, and
 - 2) determine the power of astigmatism
 - And this information is used to collapse the conoid onto the retina!

Astigmatic Correction: *Jackson Cross*



- But first: *What is a Jackson cross lens?*

Astigmatic Correction: *Jackson Cross*



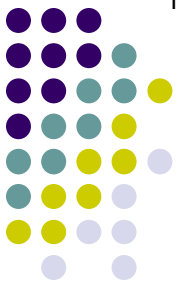
- But first: *What is a Jackson cross lens?*
 - It is a spherocylindrical lens containing plus **and** minus cylinders of equal-but-opposite powers oriented 90° apart

Astigmatic Correction: *Jackson Cross*



- But first: *What is a Jackson cross lens?*
 - It is a spherocylindrical lens containing plus ***and*** minus cylinders of equal-but-opposite powers oriented 90° apart
 - Key property: A Jackson cross lens has **no net spherical power** (i.e., its spherical equivalent power is zero)

Astigmatic Correction: *Jackson Cross*



- But first: *What is a Jackson cross lens?*
 - It is a spherocylindrical lens containing plus **and** minus cylinders of equal-but-opposite powers oriented 90° apart
 - Key property: A Jackson cross lens has **no net spherical power** (i.e., its spherical equivalent power is zero)
 - Because it has no sphere power, *a Jackson cross lens will not move the Circle of Least Confusion* when placed before an astigmatic eye

Astigmatic Correction: *Jackson Cross*



- Jackson cross lens: Spherocylindrical-notation examples

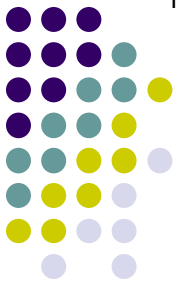
- $+1.0 -2.0 \times 090$

- $-2.0 +4.0 \times 180$

- $+0.25 - 0.50 \times 135$

Note that for each of these, S.E. = 0

Astigmatic Correction: *Jackson Cross*



- Jackson cross lens: Spherocylindrical-notation examples

- $+1.0 -2.0 \times 090$

- $-2.0 +4.0 \times 180$

- $+0.25 - 0.50 \times 135$

Note that for each of these, S.E. = 0

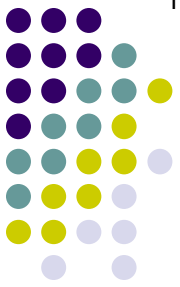
- $+1 \times 180$
 -1×090

- -2×090
 $+2 \times 180$

- $+.25 \times 045$
 $-.25 \times 135$

Here are the same Jackson cross lenses written in **power-cross notation**.

Astigmatic Correction: *Jackson Cross*



- Jackson cross lens: Spherocylindrical-notation examples

- $+1.0 -2.0 \times 090$

- $-2.0 +4.0 \times 180$

- $+0.25 - 0.50 \times 135$

Note that for each of these, S.E. = 0

- $+1 \times 180$
- -1×090

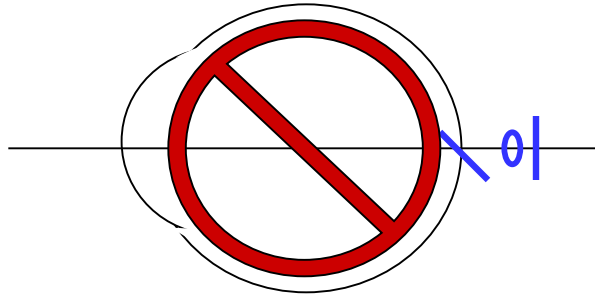
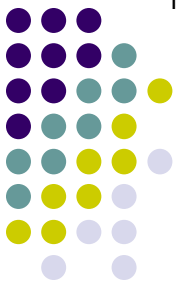
- -2×090
- $+2 \times 180$

- $+.25 \times 045$
- $-.25 \times 135$

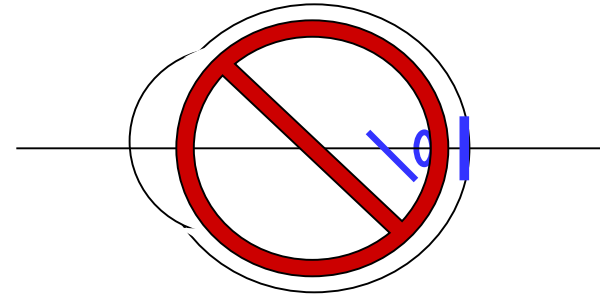
Here are the same Jackson cross lenses written in **power-cross notation**. In this format, it is easier to appreciate that each consists simply of plus and minus cylinders of identical but opposite powers, oriented 90° apart. (We'll talk more about power crosses later in this chapter.)

OKAP pearl: You must be able to recognize/identify a Jackson cross!

Astigmatic Correction: *Jackson Cross*



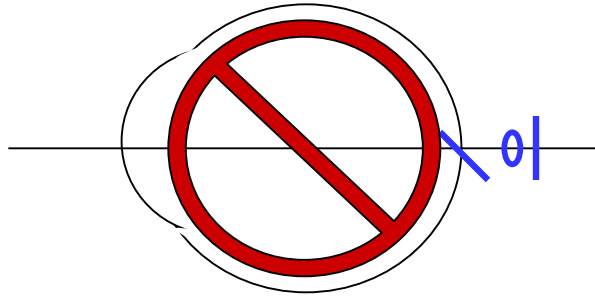
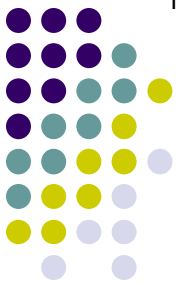
Simple Hyperopic
(if using a plus-cyl phoropter)



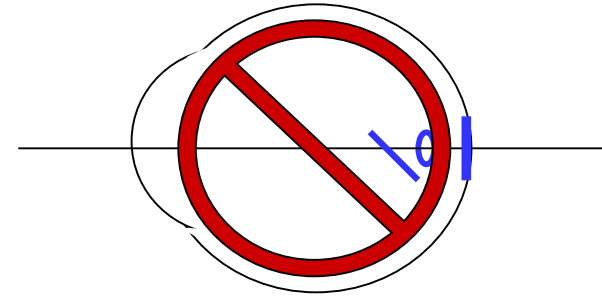
Simple Myopic
(if using a minus-cyl phoropter)

When using the Jackson cross, the starting point is **not** the same as it was for the retinoscopic approach

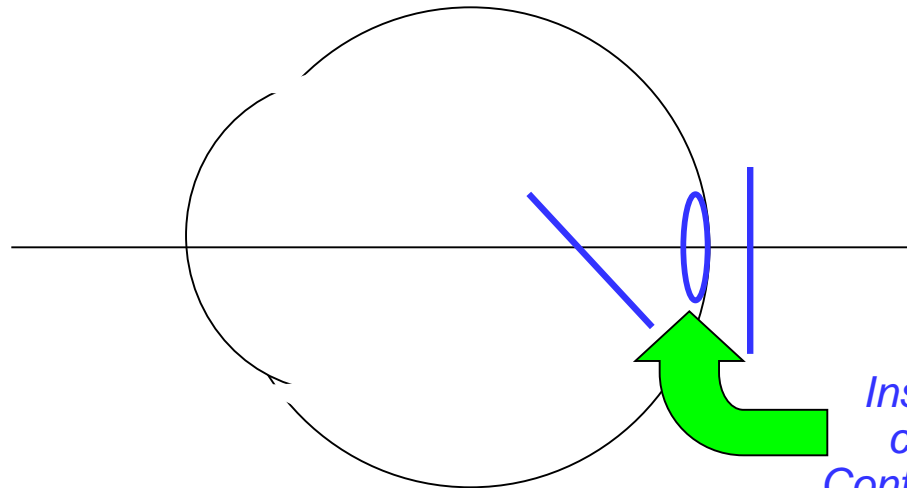
Astigmatic Correction: *Jackson Cross*



Simple Hyperopic
(if using a plus-cyl phoropter)



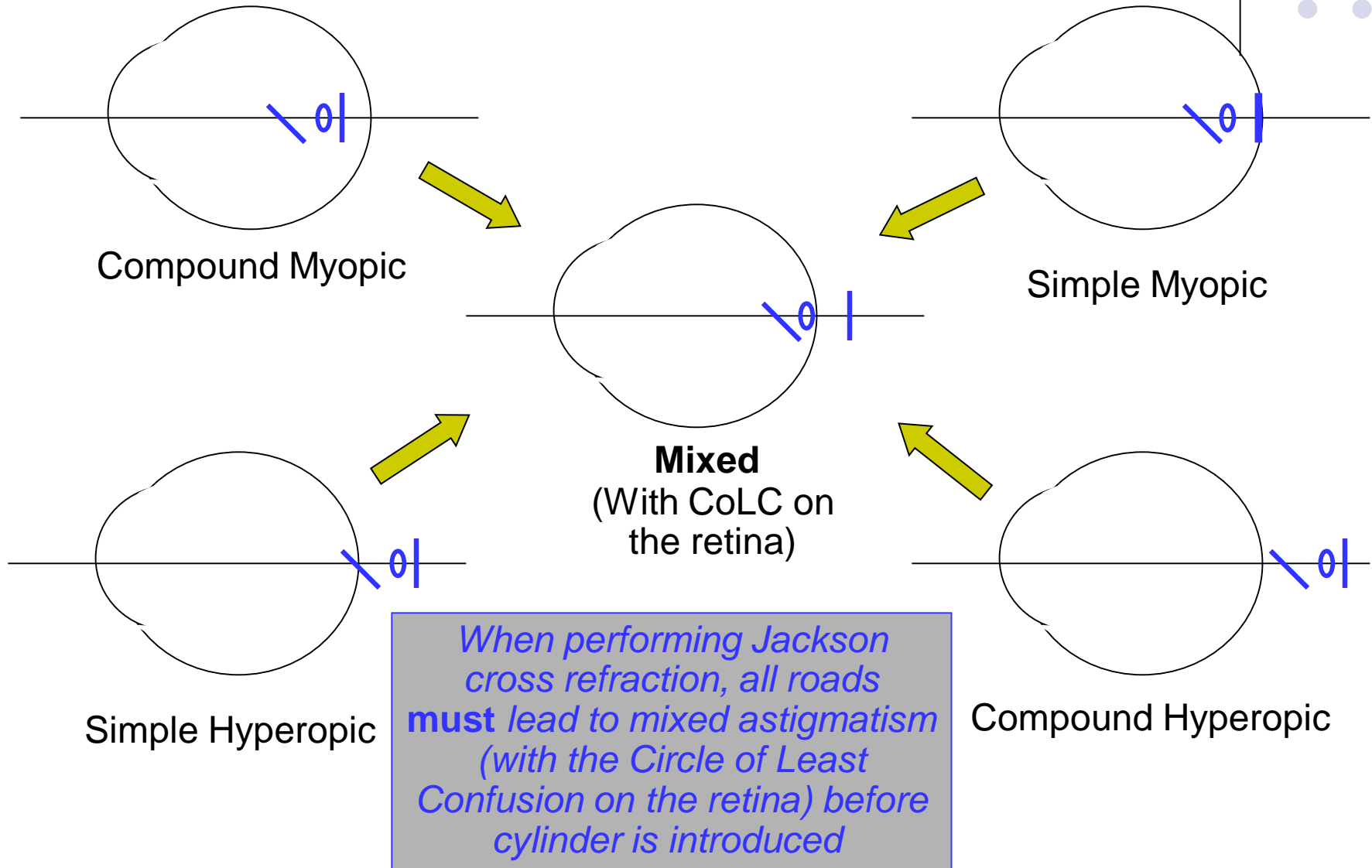
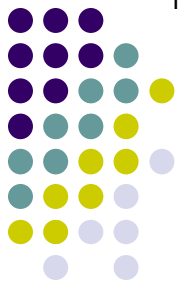
Simple Myopic
(if using a minus-cyl phoropter)



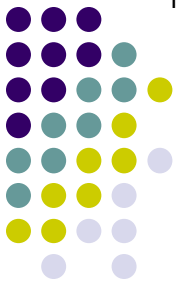
Mixed

Instead, to use the Jackson cross, the Circle of Least Confusion must be on the retina

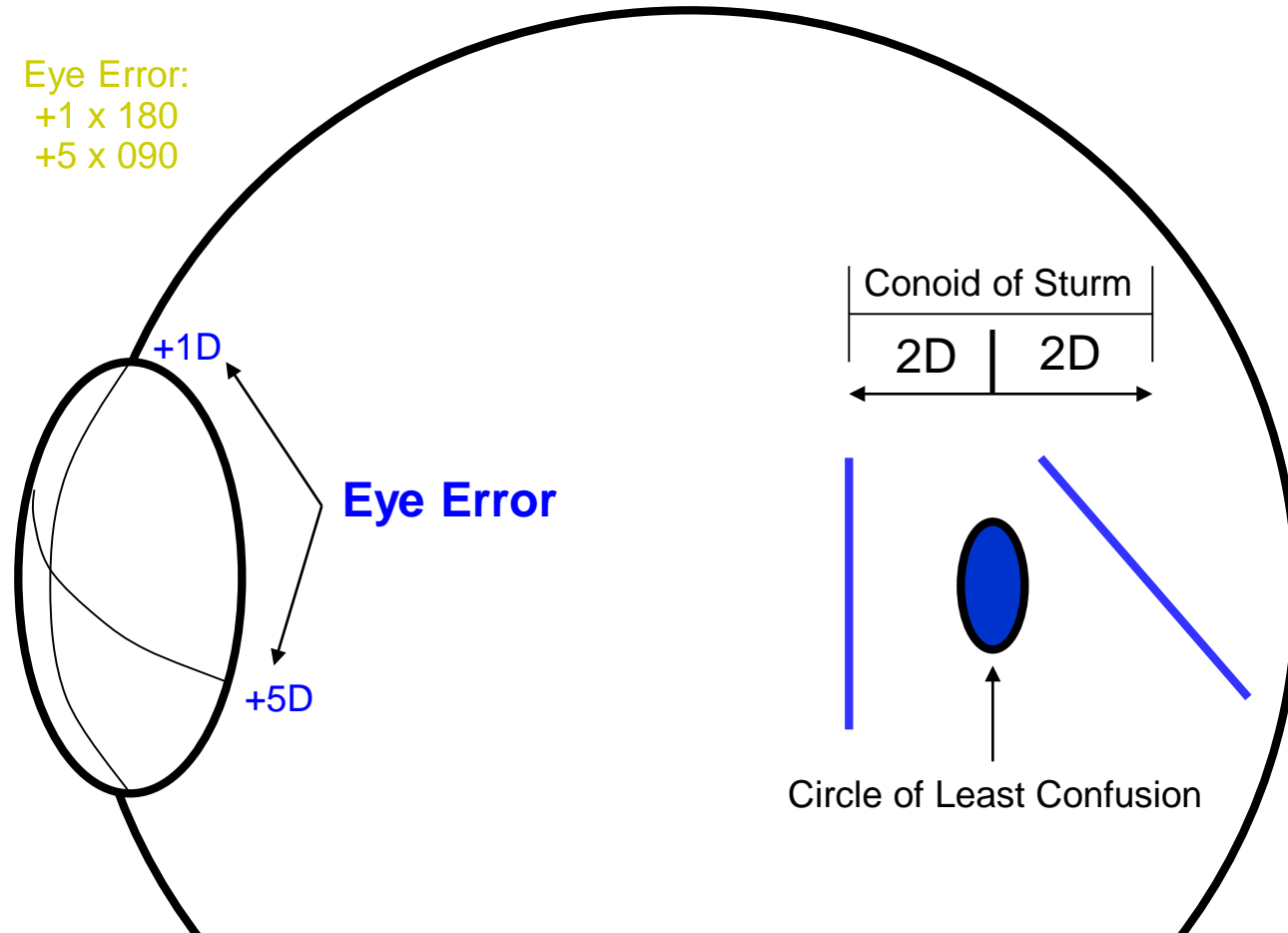
Astigmatic Correction: *Jackson Cross*



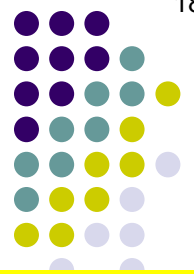
Astigmatic Correction: *Jackson Cross*



Eye Error:
+1 x 180
+5 x 090

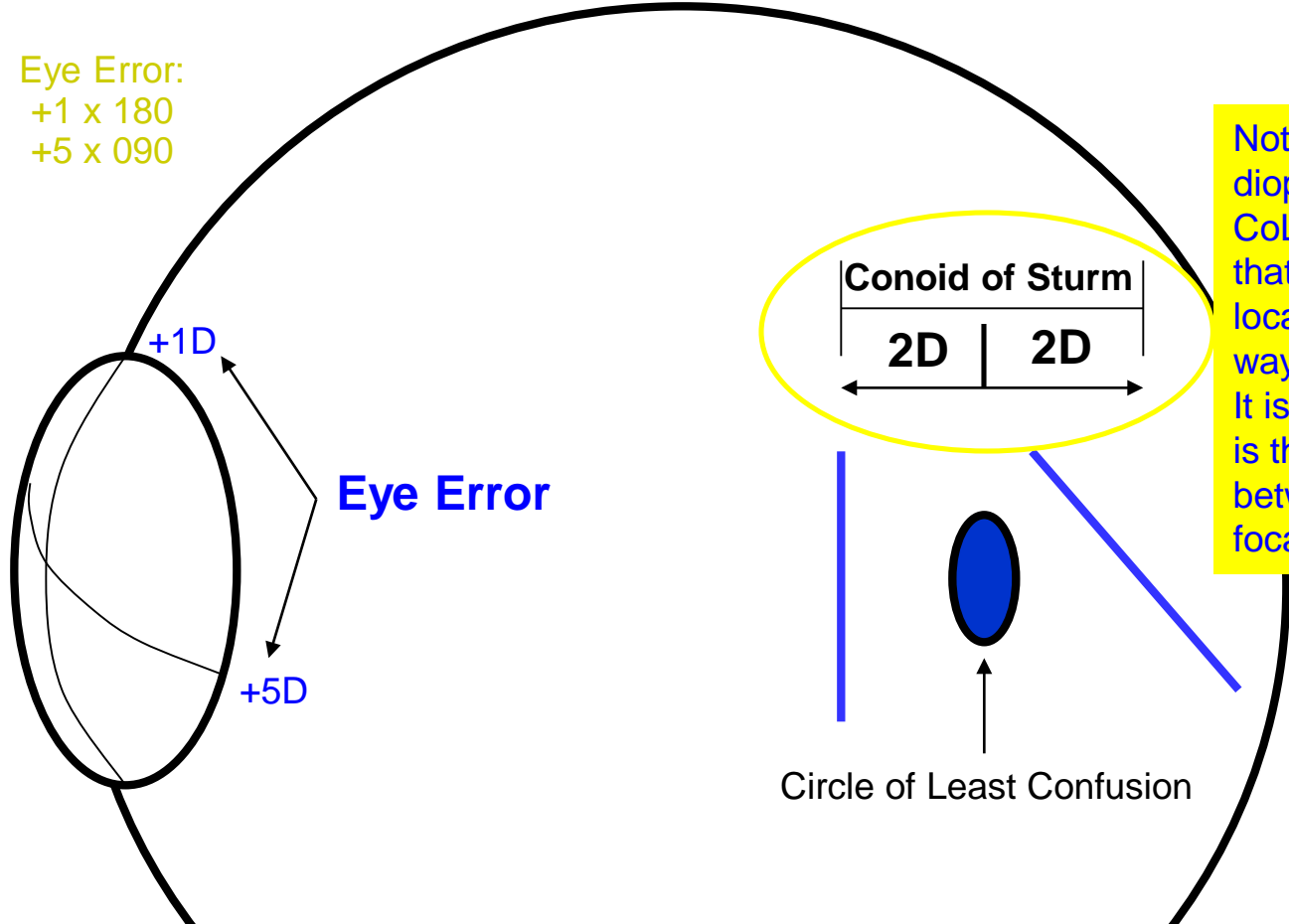


Consider this astigmatic eye.



Astigmatic Correction: *Jackson Cross*

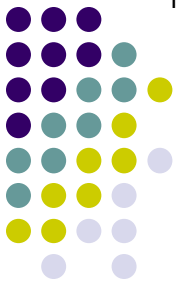
Eye Error:
+1 x 180
+5 x 090



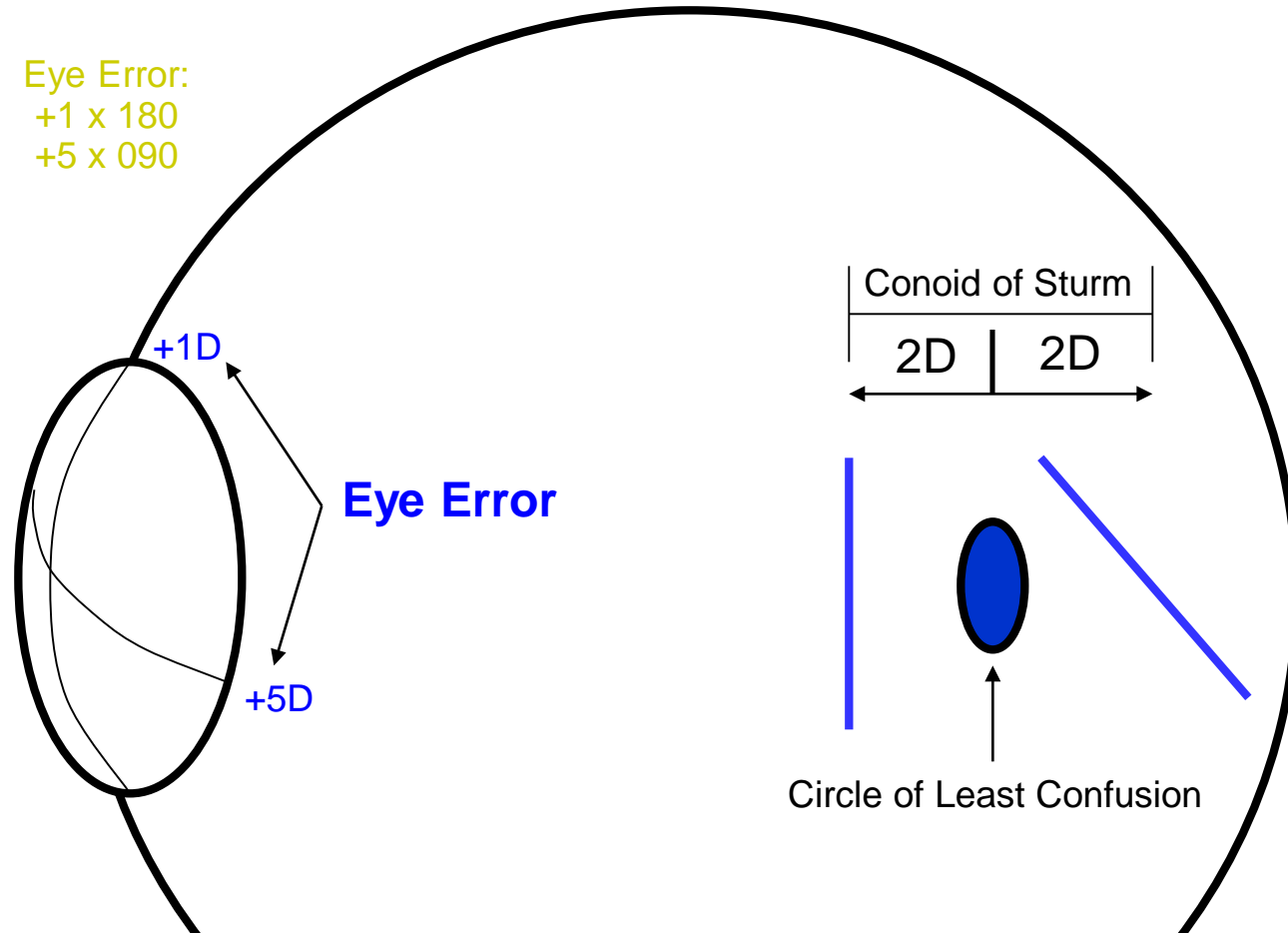
Note the conoid is four diopters wide, with the CoLC in the middle (recall that the CoLC is always located at the dioptric half-way point of its conoid). It is 4D wide because that is the difference in power between the two eye-error focal lines $[(+5)-(+1)=4]$.

Consider this astigmatic eye.

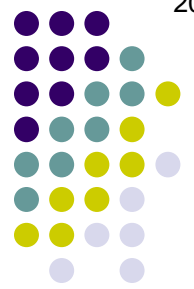
Astigmatic Correction: *Jackson Cross*



Eye Error:
 $+1 \times 180$
 $+5 \times 090$



Consider this astigmatic eye. How can we use the Jackson cross lens to neutralize its refractive error?

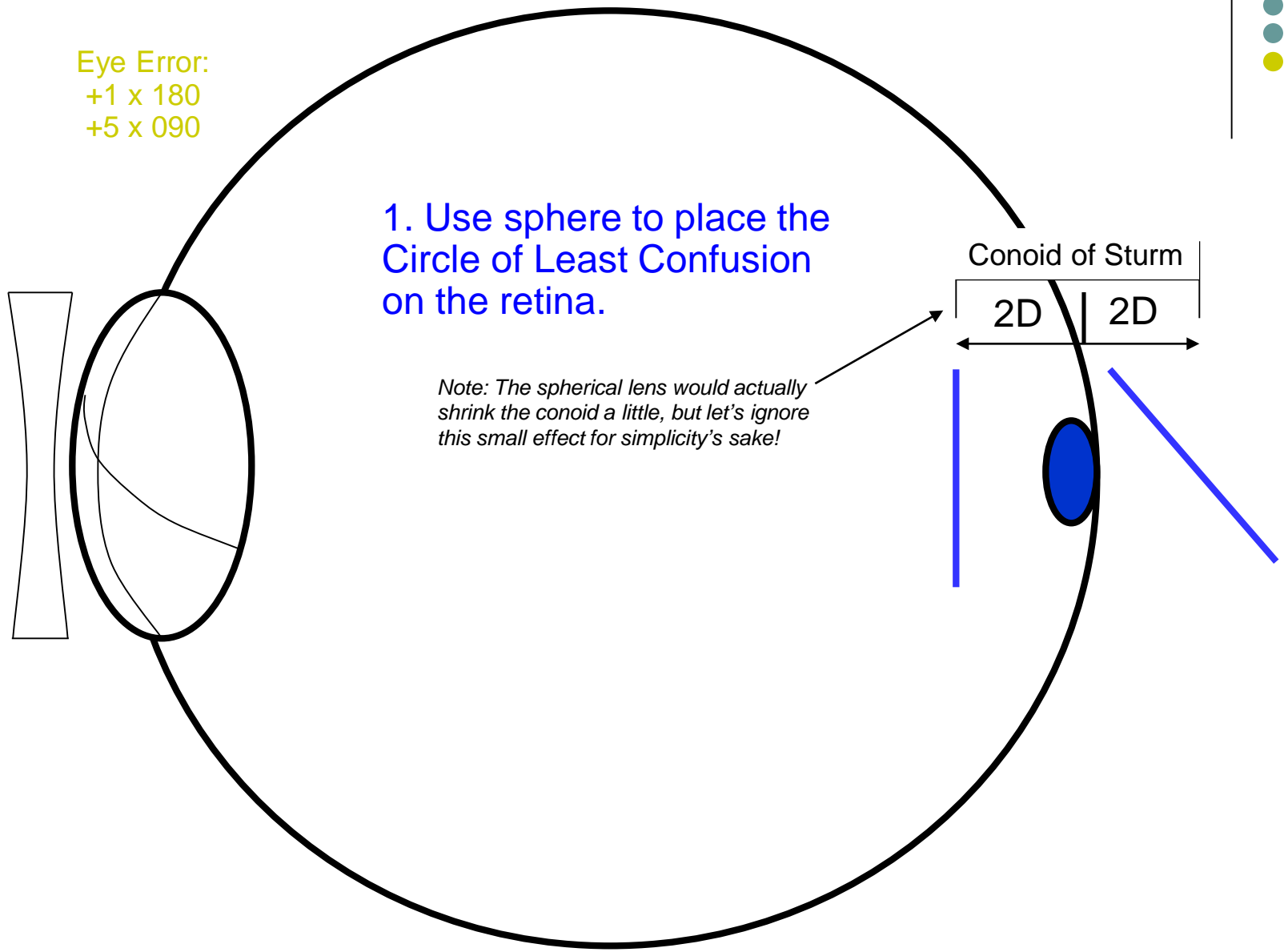


Astigmatic Correction: *Jackson Cross*

Eye Error:
+1 x 180
+5 x 090

1. Use sphere to place the
Circle of Least Confusion
on the retina.

*Note: The spherical lens would actually
shrink the conoid a little, but let's ignore
this small effect for simplicity's sake!*



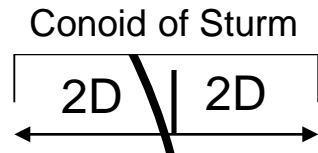
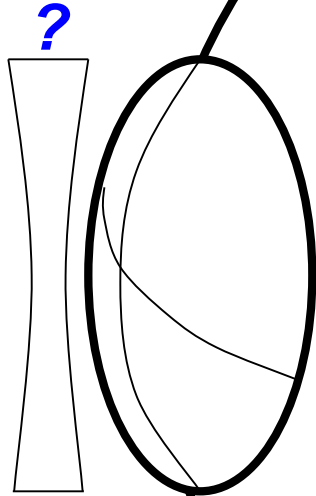


Astigmatic Correction: *Jackson Cross*

Eye Error:
+1 x 180
+5 x 090

How much sphere?

1. Use sphere to place the Circle of Least Confusion on the retina.





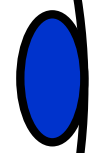
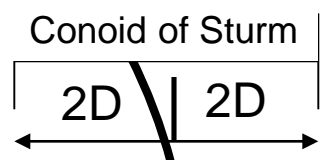
Astigmatic Correction: Jackson Cross

Eye Error:
+1 x 180
+5 x 090

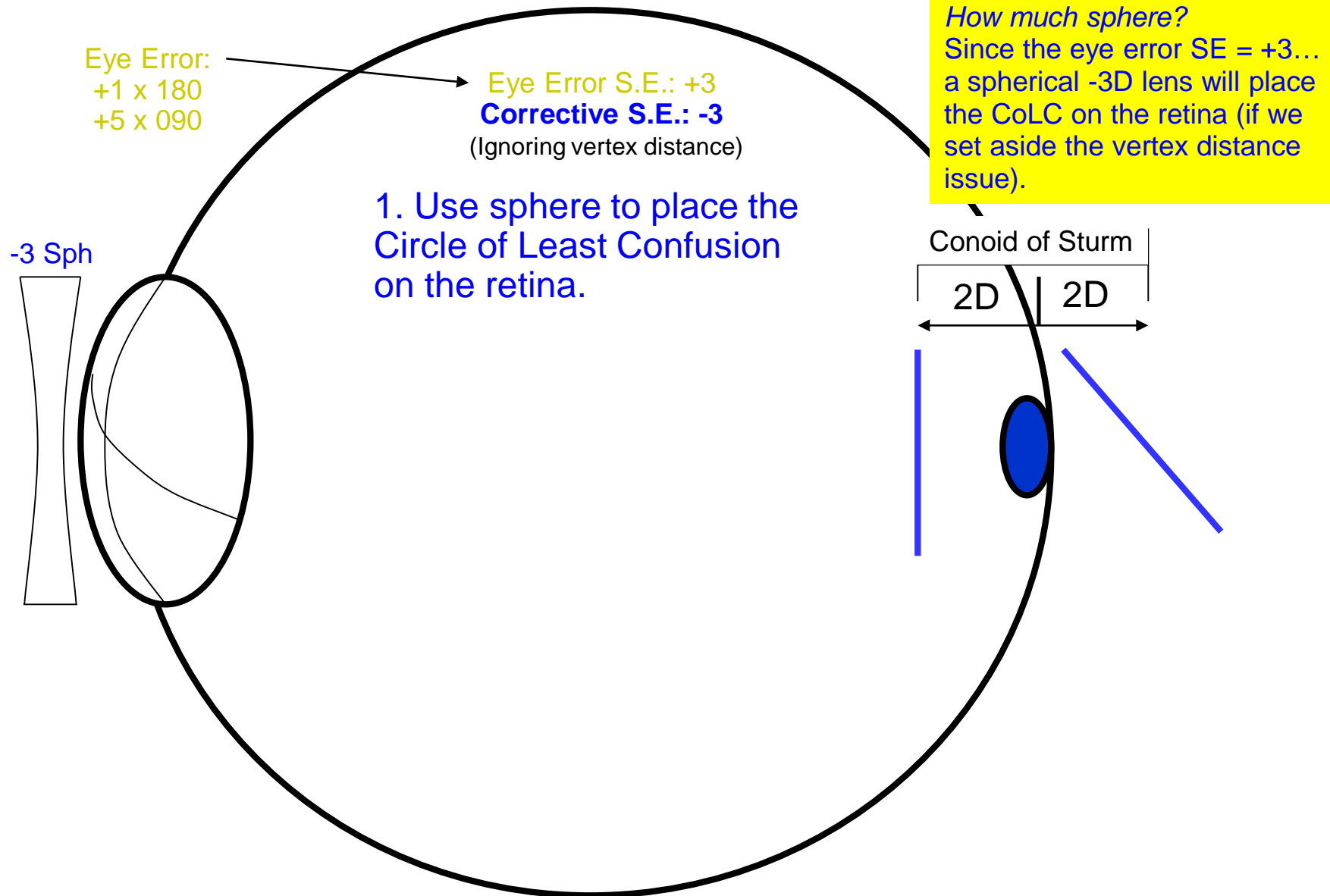
Eye Error S.E.: +3

How much sphere?
Since the eye error SE = +3...

1. Use sphere to place the
Circle of Least Confusion
on the retina.



Astigmatic Correction: *Jackson Cross*





Astigmatic Correction: Jackson Cross

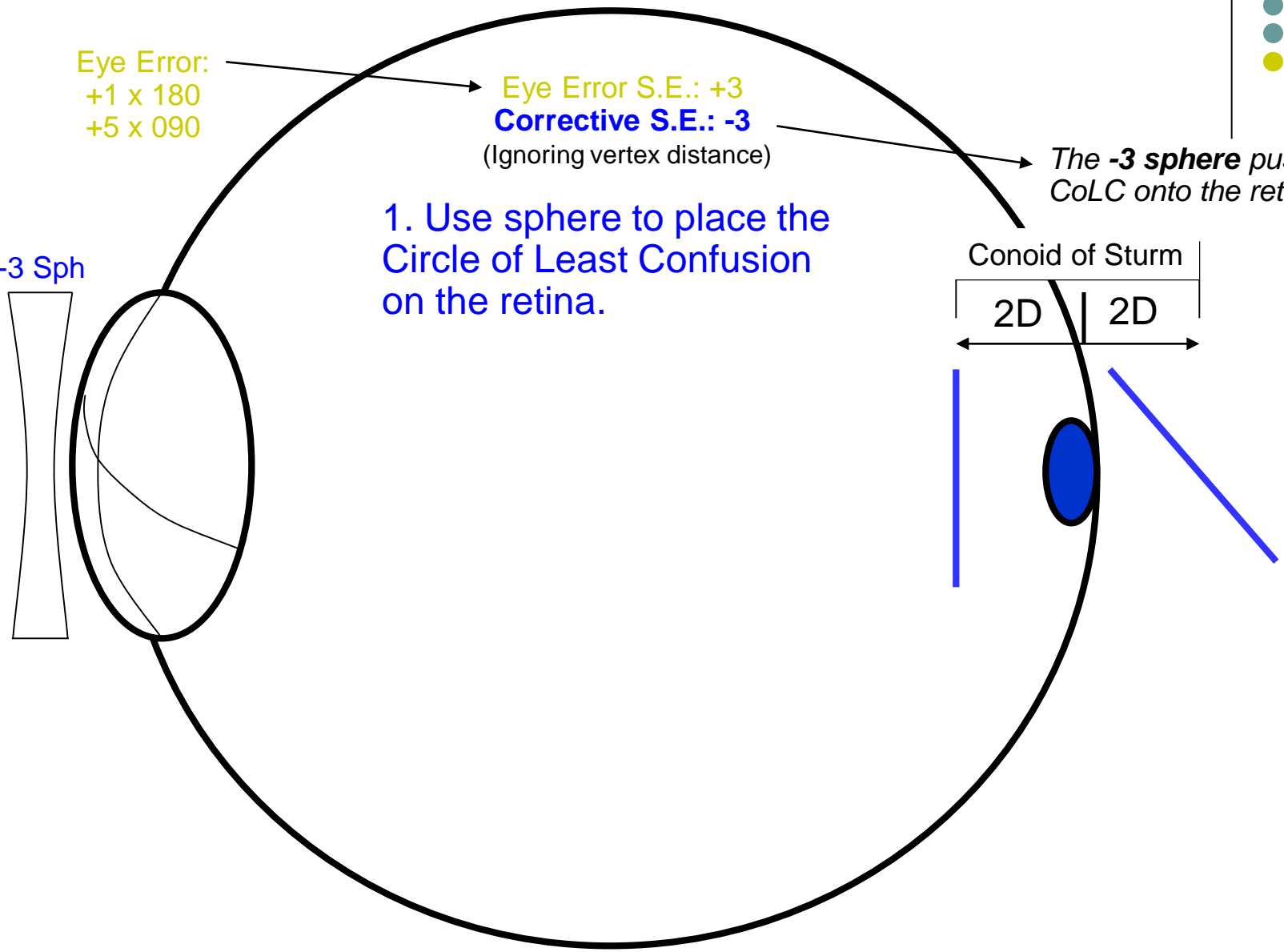
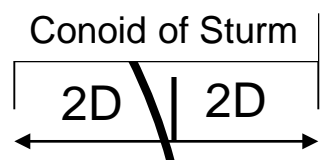
Eye Error:
+1 x 180
+5 x 090

Eye Error S.E.: +3
Corrective S.E.: -3
(Ignoring vertex distance)

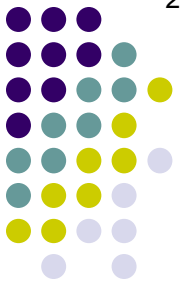
The **-3 sphere** pushes the CoLC onto the retina

1. Use sphere to place the Circle of Least Confusion on the retina.

-3 Sph

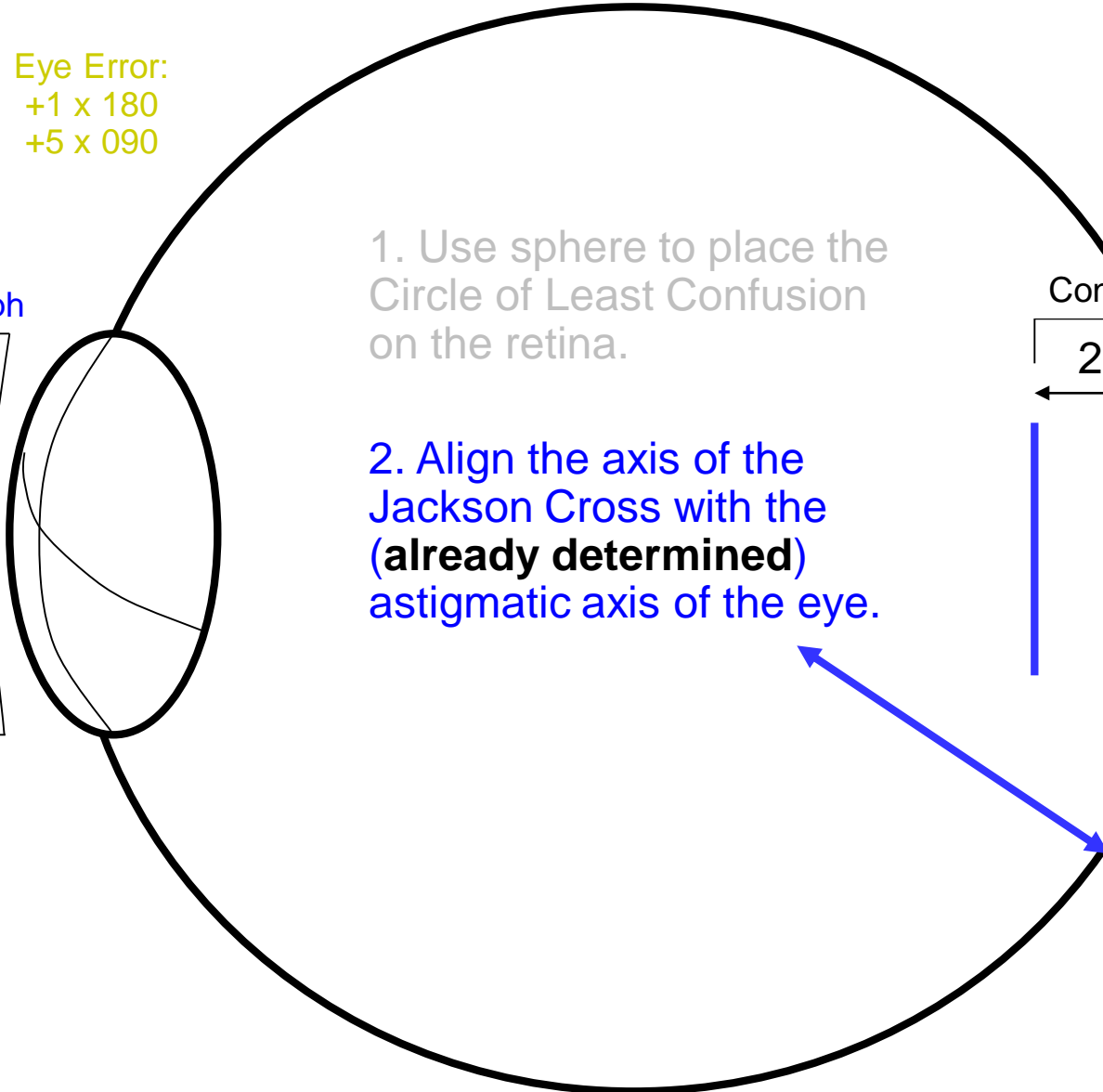


Astigmatic Correction: *Jackson Cross*



Eye Error:
+1 x 180
+5 x 090

-3 Sph



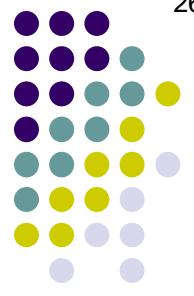
1. Use sphere to place the Circle of Least Confusion on the retina.

2. Align the axis of the Jackson Cross with the **(already determined)** astigmatic axis of the eye.

Conoid of Sturm

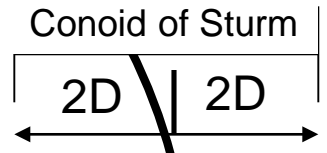
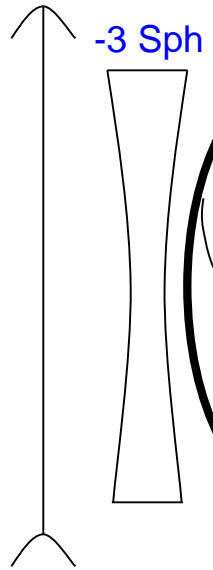
2D | 2D

NOTE: We are discussing determination of cylinder **power** first—it's easier to understand. But in practice, **axis determination** must be done first. (We'll get to it shortly.)

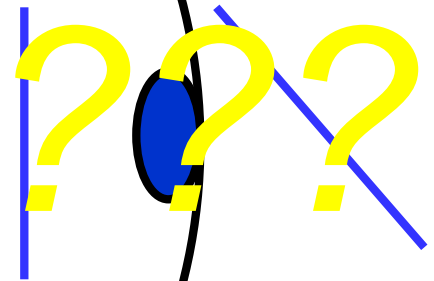


Astigmatic Correction: Jackson Cross

Eye Error:
+1 x 180
+5 x 090

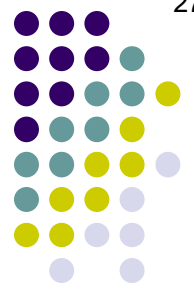


2. Align the axis of the Jackson Cross with the (already determined) astigmatic axis of the eye.



What effect does the Jackson cross lens have on the Conoid of Sturm when it is oriented like this??

+1x090
-1x180
↑
Jackson Cross



Astigmatic Correction: *Jackson Cross*

Eye Error:
+1 x 180
+5 x 090

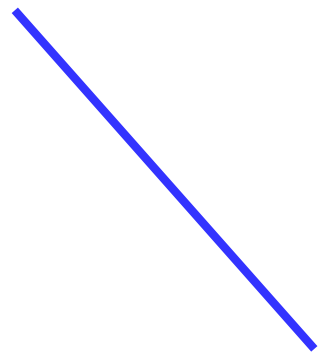
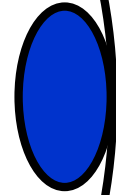
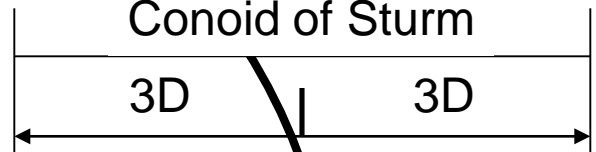
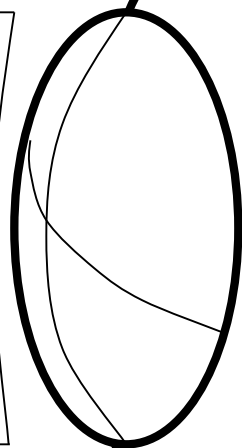
This alignment of the cross lens moves the focal lines **farther apart.**

Conoid of Sturm

3D

3D

-3 Sph



+1x090
-1x180

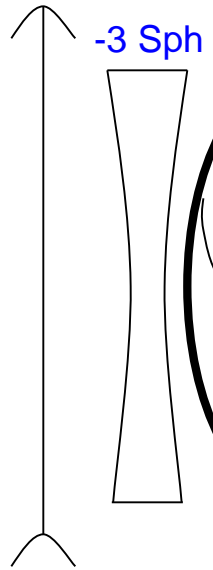
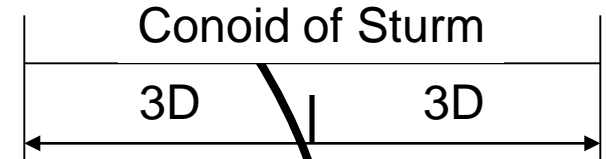
↑
Jackson Cross



Astigmatic Correction: Jackson Cross

Eye Error:
+1 x 180
+5 x 090

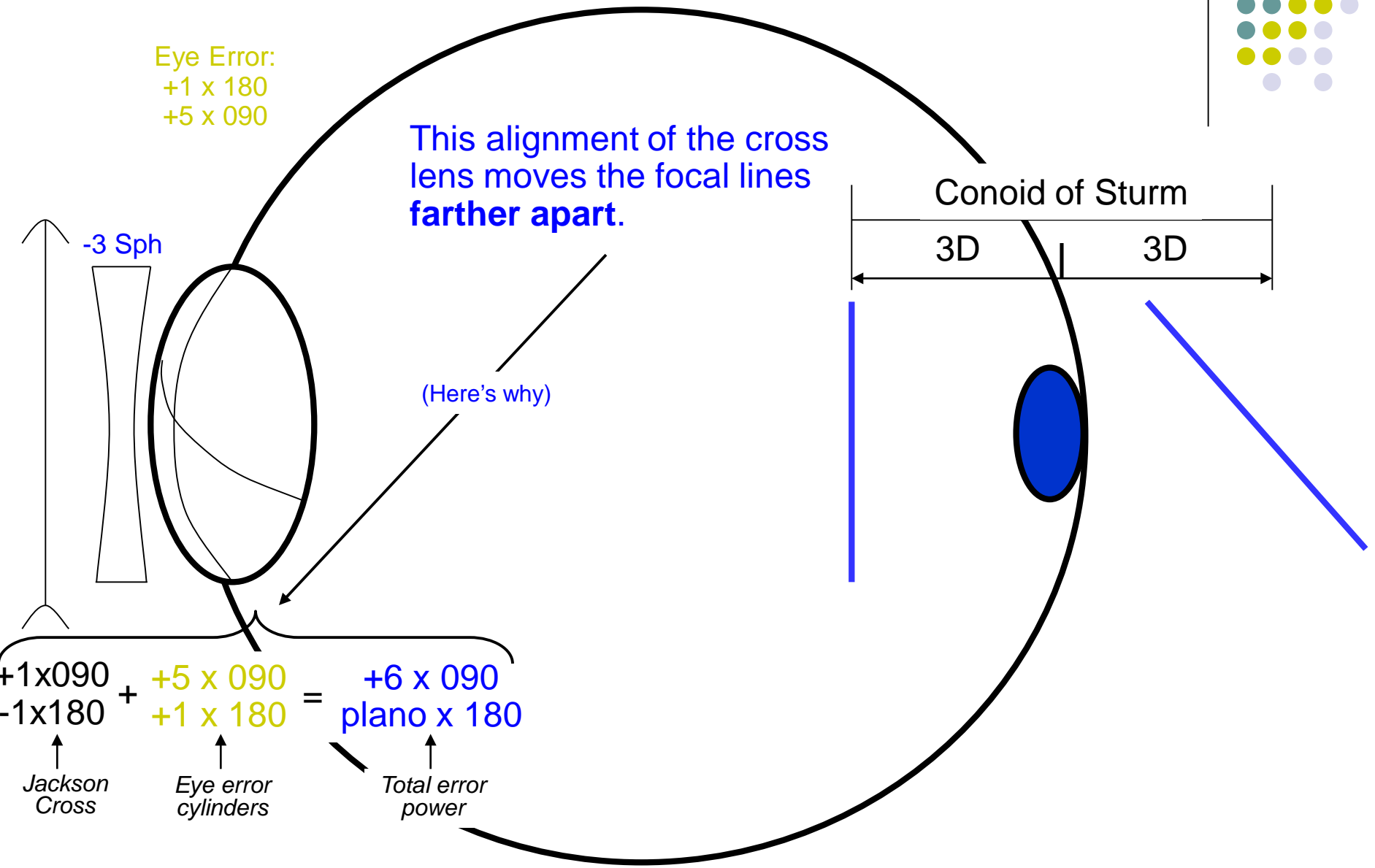
This alignment of the cross lens moves the focal lines farther apart.

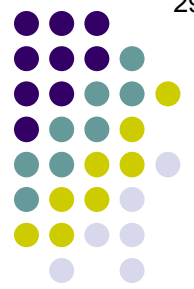


(Here's why)

$$\begin{array}{r}
 +1 \times 090 \\
 -1 \times 180 \\
 \hline
 \end{array}
 +
 \begin{array}{r}
 +5 \times 090 \\
 +1 \times 180 \\
 \hline
 \end{array}
 =
 \begin{array}{r}
 +6 \times 090 \\
 \text{plano} \times 180 \\
 \hline
 \end{array}$$

↑ Jackson Cross ↑ Eye error cylinders ↑ Total error power

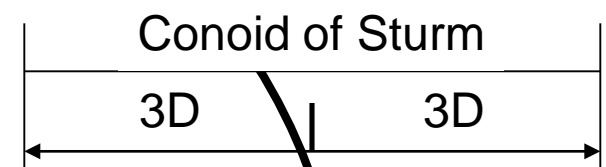




Astigmatic Correction: Jackson Cross

Eye Error:
+1 x 180
+5 x 090

This alignment of the cross lens moves the focal lines farther apart.



(Here's why)

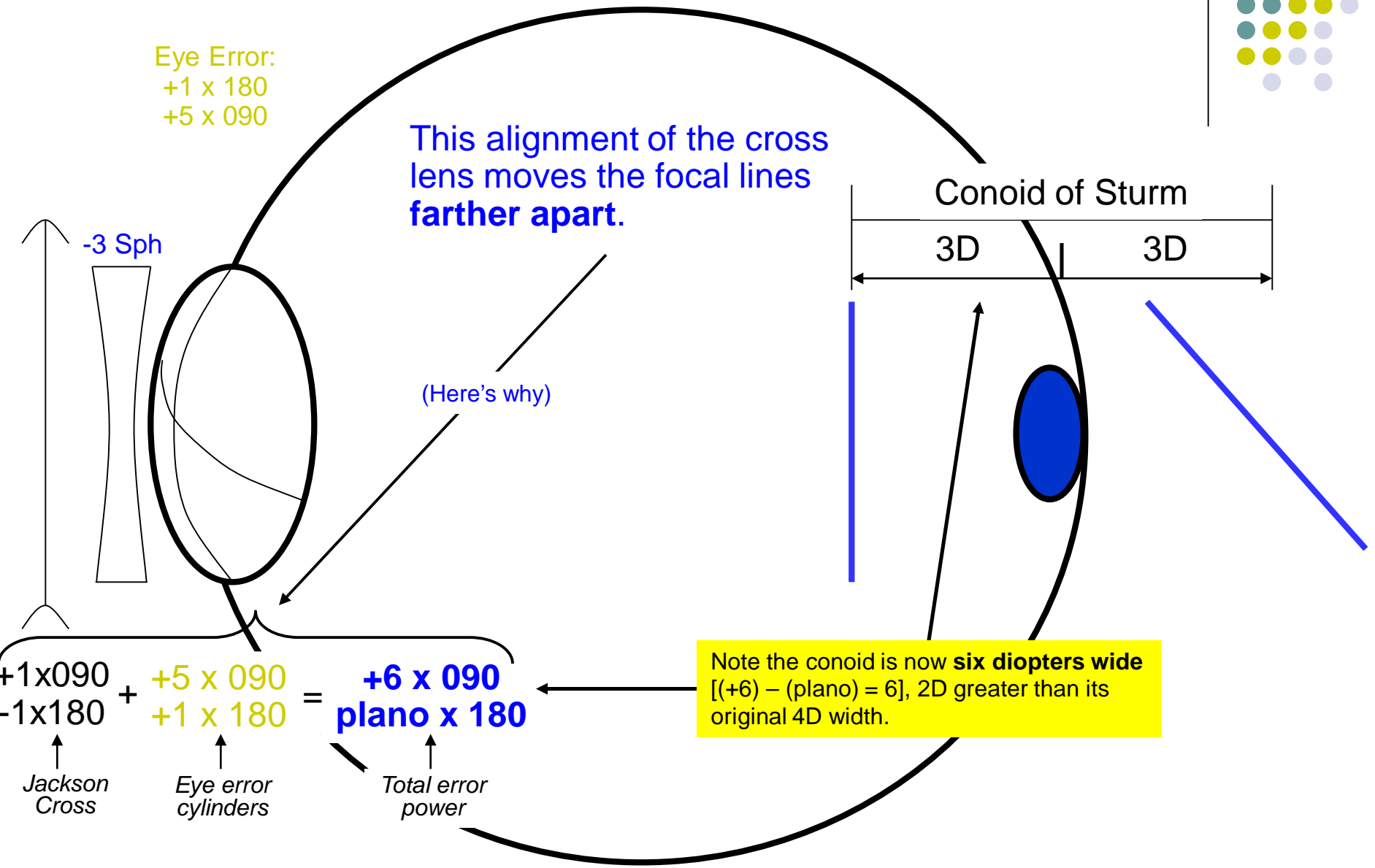
-3 Sph

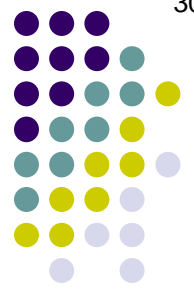


$$\begin{array}{r}
 +1 \times 090 \\
 -1 \times 180 \\
 \hline
 \end{array}
 +
 \begin{array}{r}
 +5 \times 090 \\
 +1 \times 180 \\
 \hline
 \end{array}
 =
 \begin{array}{r}
 +6 \times 090 \\
 \text{plano} \times 180 \\
 \hline
 \end{array}$$

↑ Jackson Cross ↑ Eye error cylinders ↑ Total error power

Note the conoid is now **six diopters wide** [(+6) - (plano) = 6], 2D greater than its original 4D width.



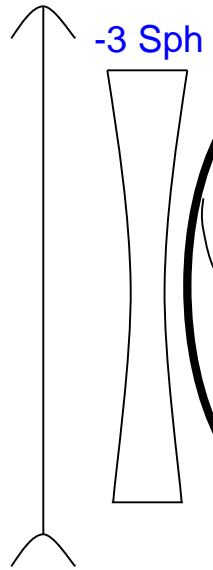
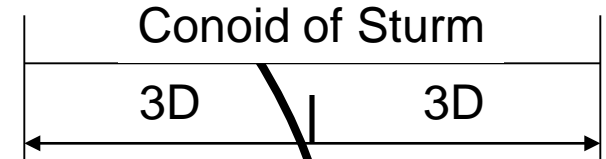


Astigmatic Correction: Jackson Cross

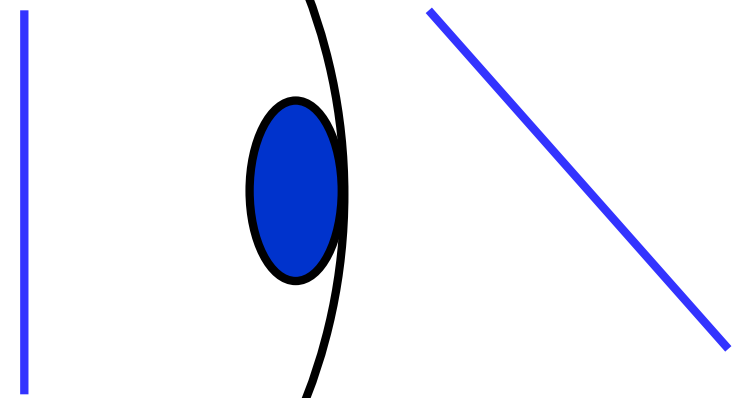
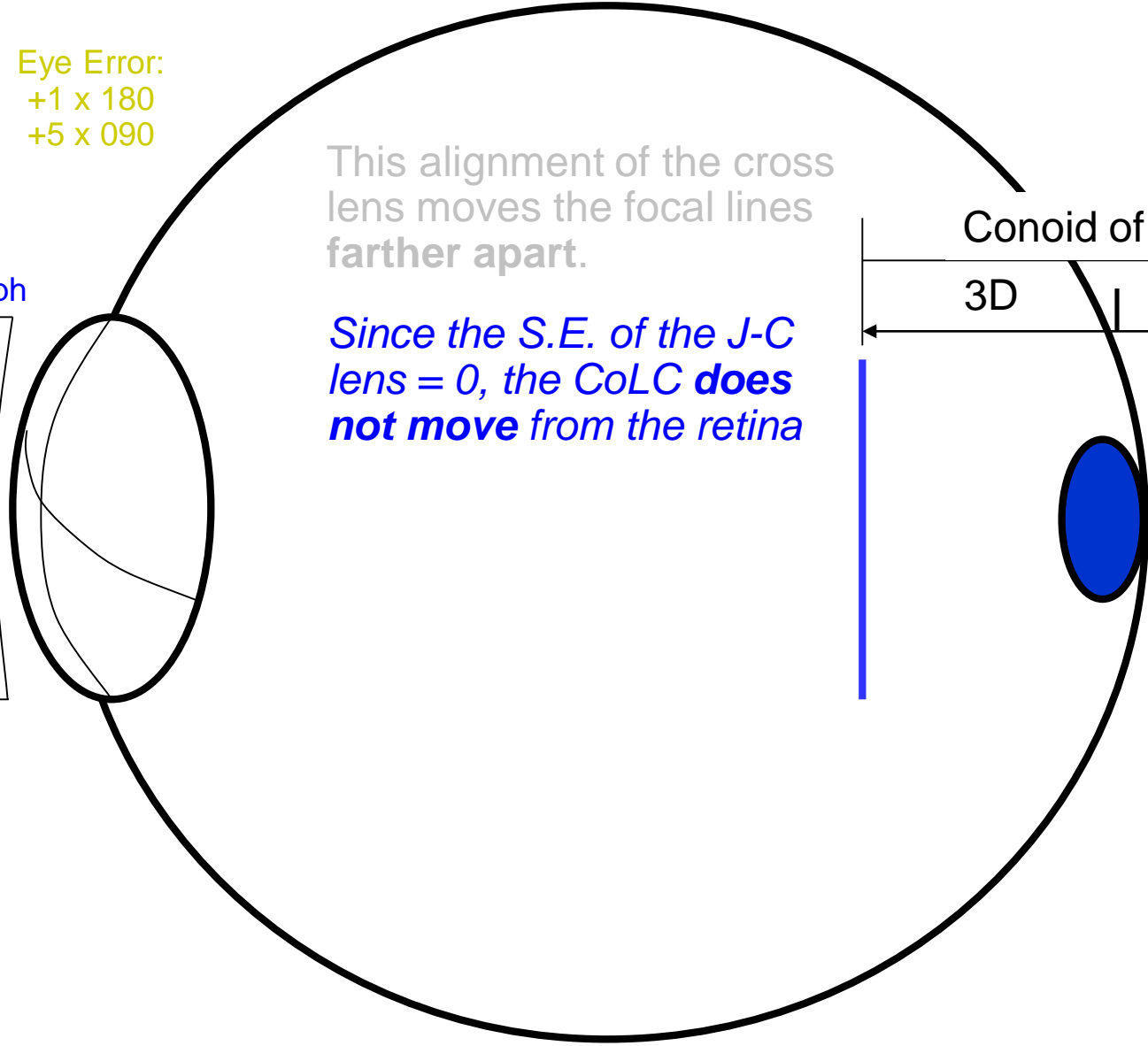
Eye Error:
+1 x 180
+5 x 090

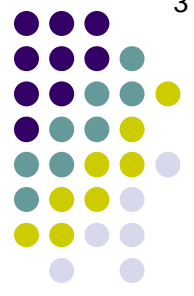
This alignment of the cross lens moves the focal lines farther apart.

Since the S.E. of the J-C lens = 0, the CoLC does not move from the retina



+1x090
-1x180
↑
Jackson Cross





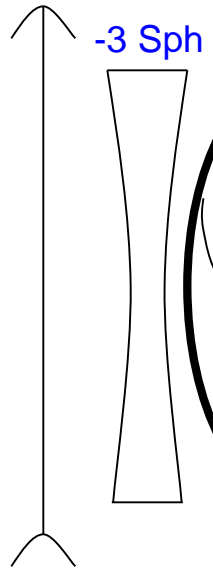
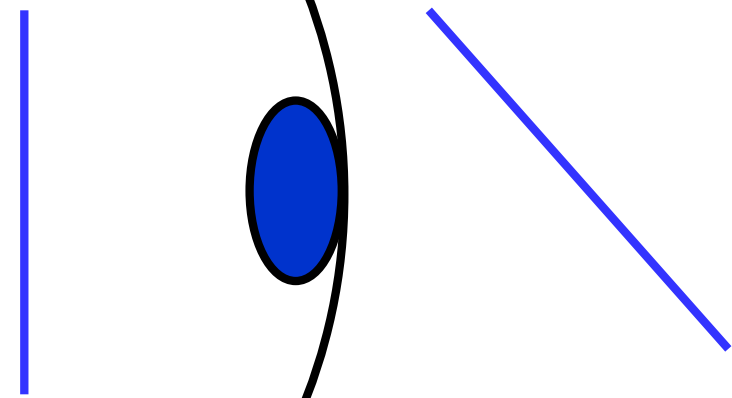
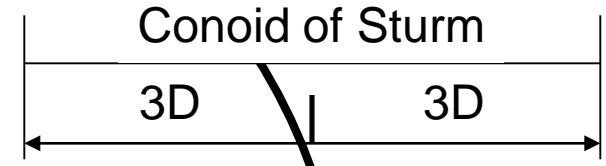
Astigmatic Correction: *Jackson Cross*

Eye Error:
+1 x 180
+5 x 090

This alignment of the cross lens moves the focal lines farther apart.

Since the S.E. of the J-C lens = 0, the CoLC does not move from the retina

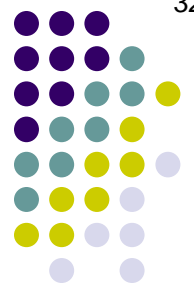
The focal lines become **longer**, which makes the Circle of Least Confusion **larger**.



-3 Sph

+1x090
-1x180

↑
Jackson Cross



Astigmatic Correction: Jackson Cross

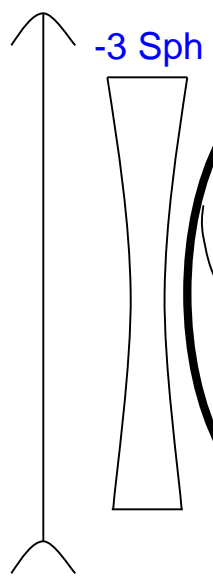
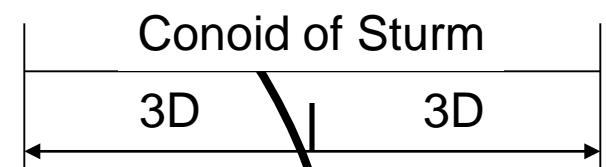
Eye Error:
+1 x 180
+5 x 090

This alignment of the cross lens moves the focal lines farther apart.

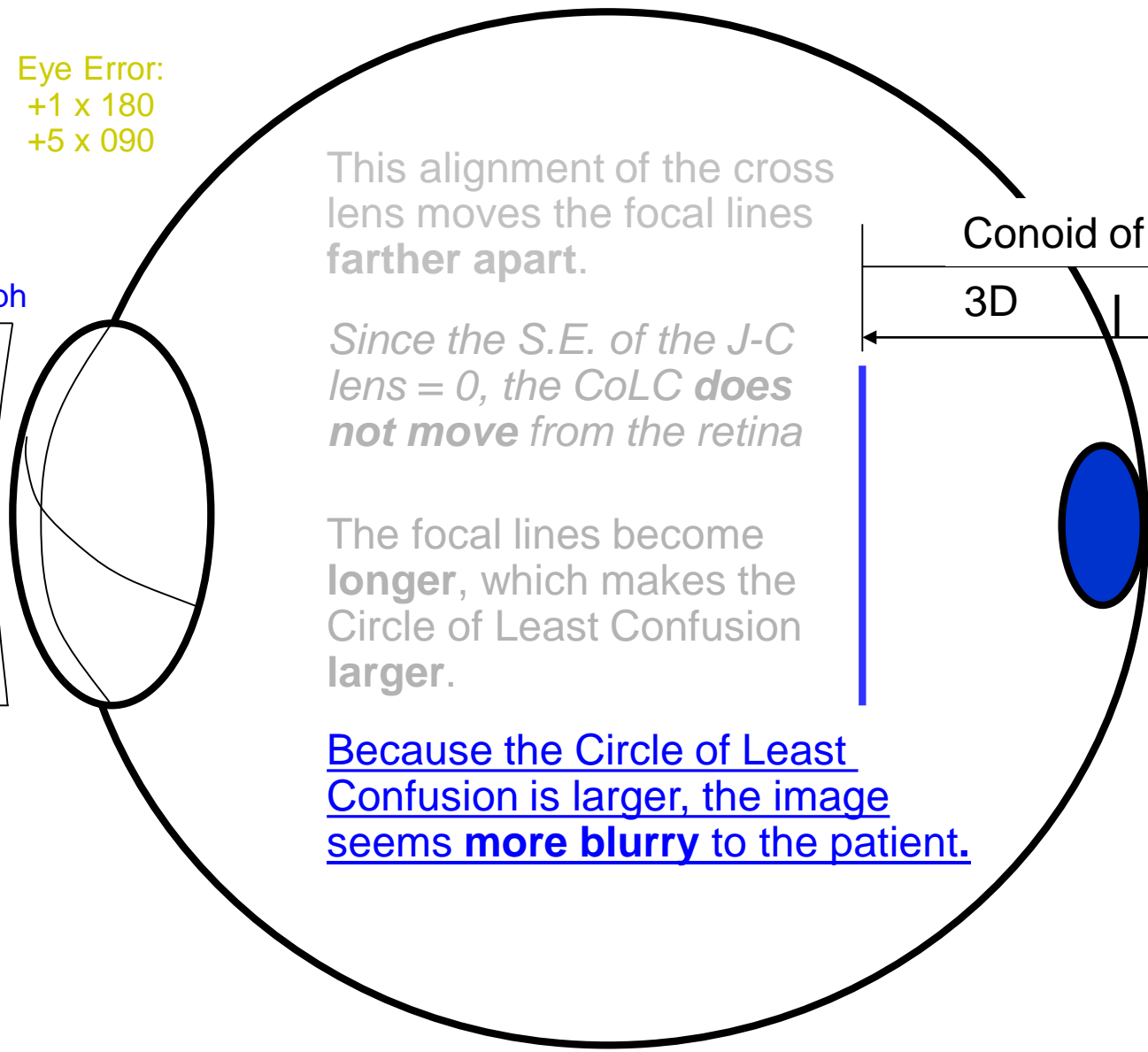
Since the S.E. of the J-C lens = 0, the CoLC **does not move** from the retina

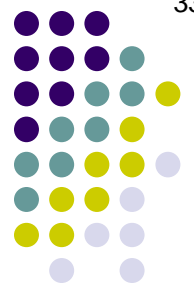
The focal lines become longer, which makes the Circle of Least Confusion larger.

Because the Circle of Least Confusion is larger, the image seems **more blurry** to the patient.



+1x090
-1x180
↑
Jackson Cross





Astigmatic Correction: Jackson Cross

Eye Error:
+1 x 180
+5 x 090

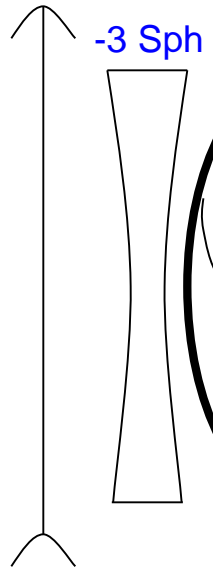
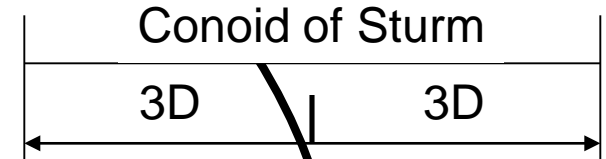
This alignment of the cross lens moves the focal lines farther apart.

Since the S.E. of the J-C lens = 0, the CoLC **does not move** from the retina

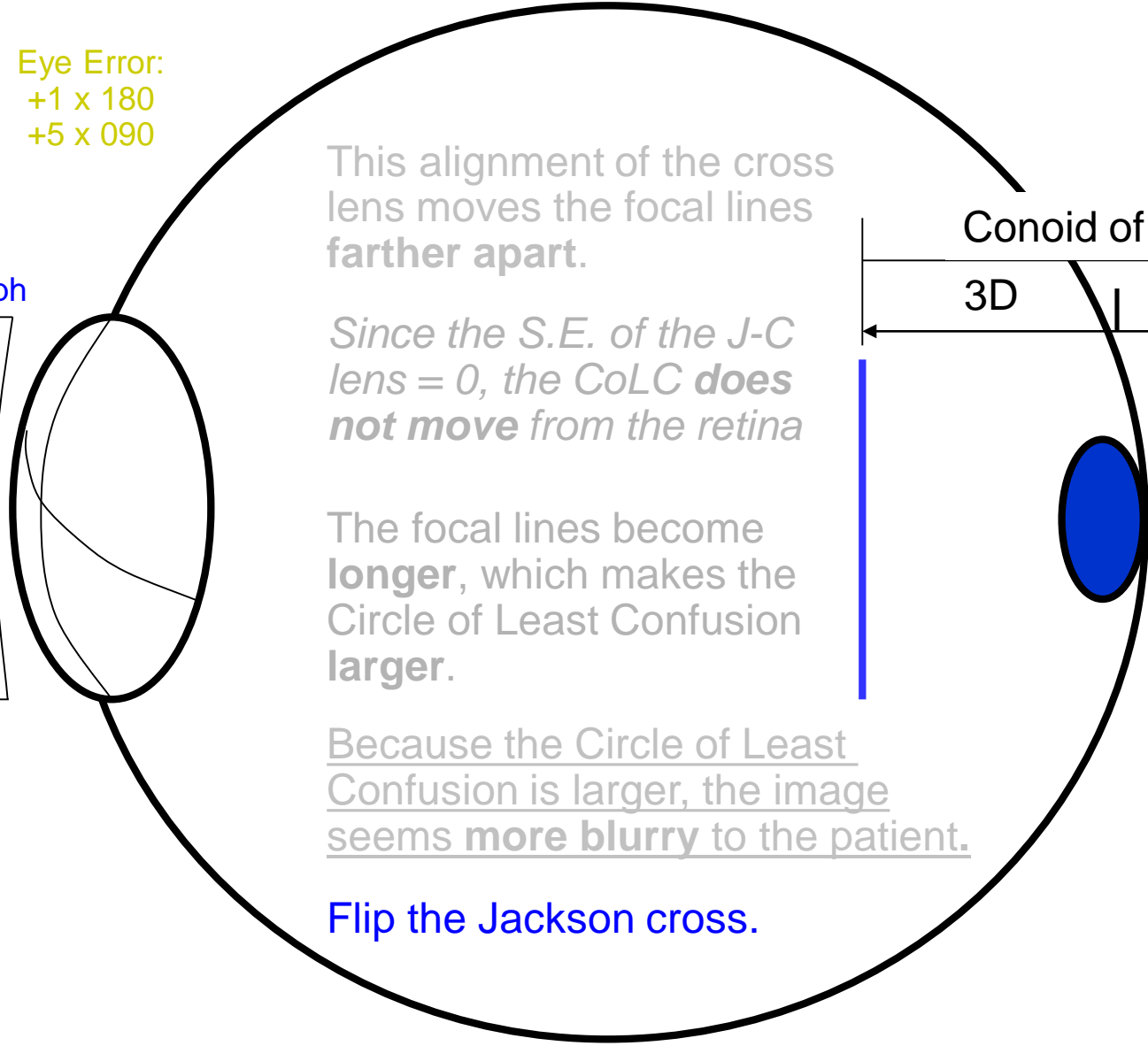
The focal lines become longer, which makes the Circle of Least Confusion larger.

Because the Circle of Least Confusion is larger, the image seems more blurry to the patient.

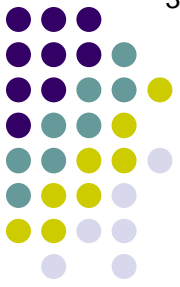
Flip the Jackson cross.



+1x090
-1x180
↑
Jackson Cross

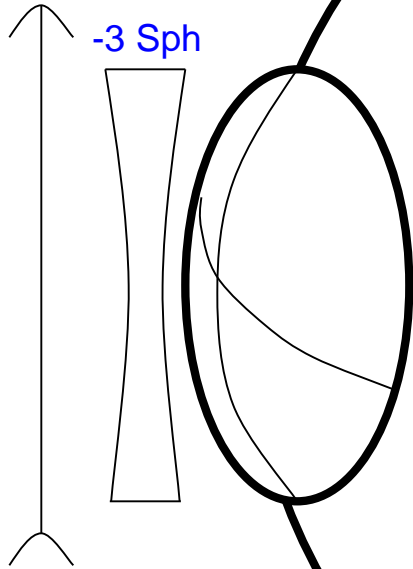


Astigmatic Correction: *Jackson Cross*



Eye Error:
+1 x 180
+5 x 090

-3 Sph

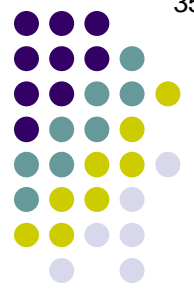


???

What happens to the Conoid when the Jackson cross is flipped?

-1x090
+1x180

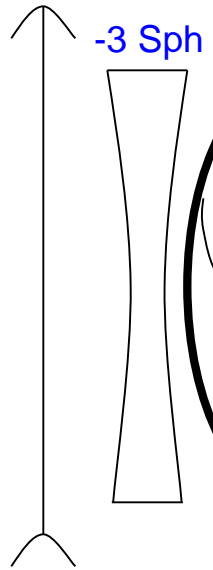
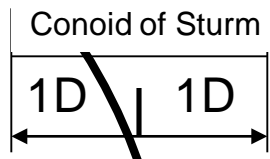
Note the change!



Astigmatic Correction: *Jackson Cross*

Eye Error:
+1 x 180
+5 x 090

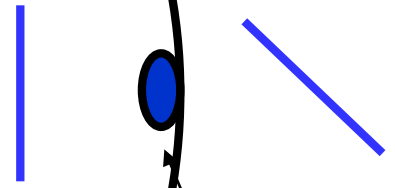
This alignment of the cross lens moves the focal lines **closer together**.



-3 Sph

-1x090
+1x180

Jackson Cross



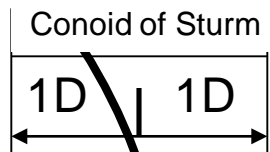
Since the S.E. of the J-C lens = 0, the CoLC **does not move** from the retina



Astigmatic Correction: Jackson Cross

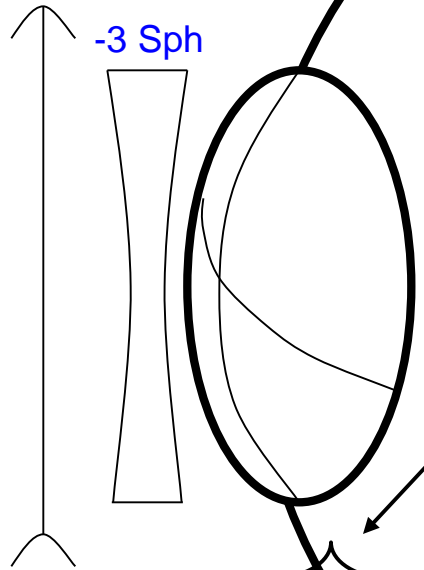
Eye Error:
+1 x 180
+5 x 090

This alignment of the cross lens moves the focal lines closer together.



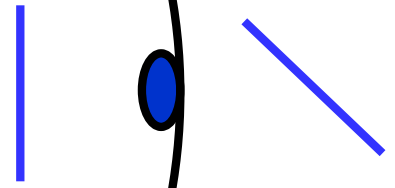
(Here's why)

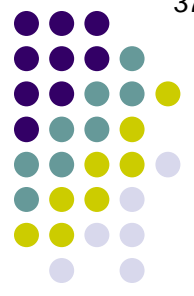
-3 Sph



$$\begin{array}{r}
 -1 \times 090 \\
 +1 \times 180 \\
 \hline
 \end{array}
 +
 \begin{array}{r}
 +5 \times 090 \\
 +1 \times 180 \\
 \hline
 \end{array}
 =
 \begin{array}{r}
 +4 \times 090 \\
 +2 \times 180 \\
 \hline
 \end{array}$$

↑ Jackson Cross ↑ Eye error cylinders ↑ Total error power

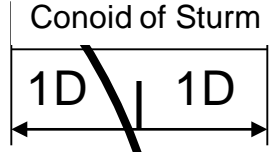




Astigmatic Correction: Jackson Cross

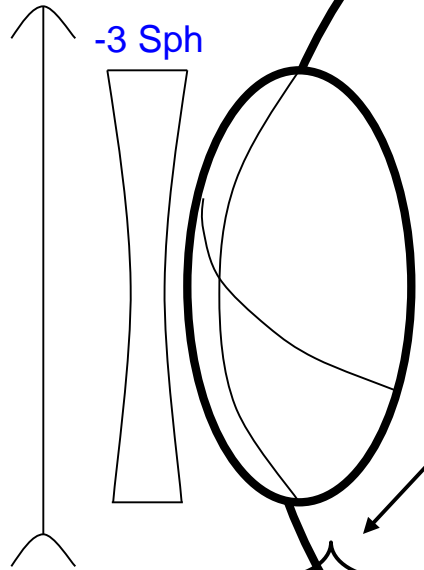
Eye Error:
+1 x 180
+5 x 090

This alignment of the cross lens moves the focal lines closer together.



(Here's why)

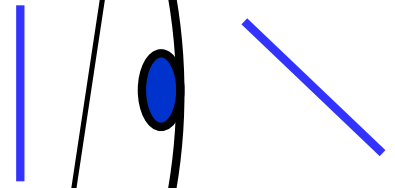
-3 Sph



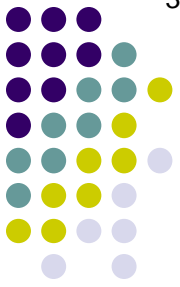
$$\begin{array}{r}
 -1 \times 090 \\
 +1 \times 180 \\
 \hline
 \end{array}
 +
 \begin{array}{r}
 +5 \times 090 \\
 +1 \times 180 \\
 \hline
 \end{array}
 =
 \begin{array}{r}
 +4 \times 090 \\
 +2 \times 180 \\
 \hline
 \end{array}$$

Jackson Cross Eye error cylinders Total error power

Note the conoid is now **two diopters wide** [(+4) - (+2) = 2], 4D less than it was before this latest change.



Astigmatic Correction: *Jackson Cross*



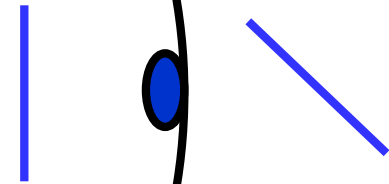
Eye Error:
+1 x 180
+5 x 090

This alignment of the cross lens moves the focal lines **closer together**.

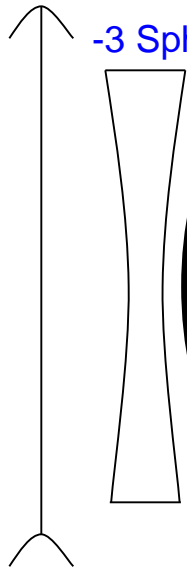
The focal lines become **shorter**, which makes the Circle of Least Confusion **smaller**.

Conoid of Sturm

1D | 1D

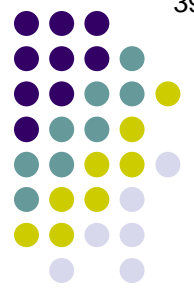


-3 Sph



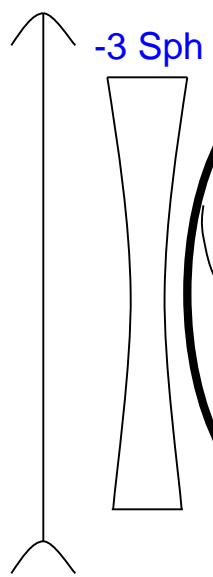
-1x090
+1x180

↑
Jackson Cross



Astigmatic Correction: *Jackson Cross*

Eye Error:
+1 x 180
+5 x 090



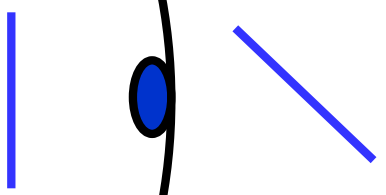
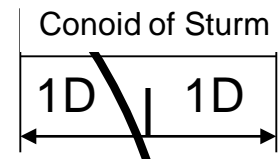
-3 Sph

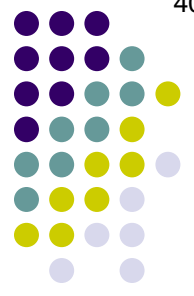
-1x090
+1x180
↑
Jackson Cross

This alignment of the cross lens moves the focal lines **closer together**.

The focal lines become **shorter**, which makes the Circle of Least Confusion **smaller**.

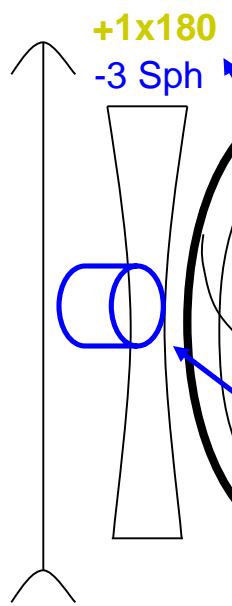
Because the Circle of Least Confusion is smaller, the image seems **less blurry** to the patient.





Astigmatic Correction: Jackson Cross

Eye Error:
+1 x 180
+5 x 090



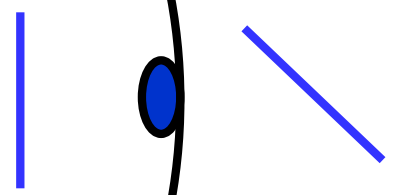
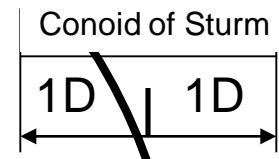
-1x090
+1x180
↑
Jackson Cross

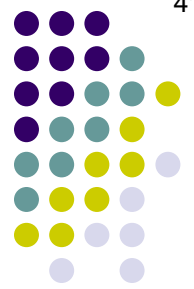
This alignment of the cross lens moves the focal lines closer together.

The focal lines become **shorter**, which makes the Circle of Least Confusion **smaller**.

Because the Circle of Least Confusion is smaller, the image seems **less blurry** to the patient.

Because this is less blurry, cylinder of **+1 x 180** is added at the phoropter.

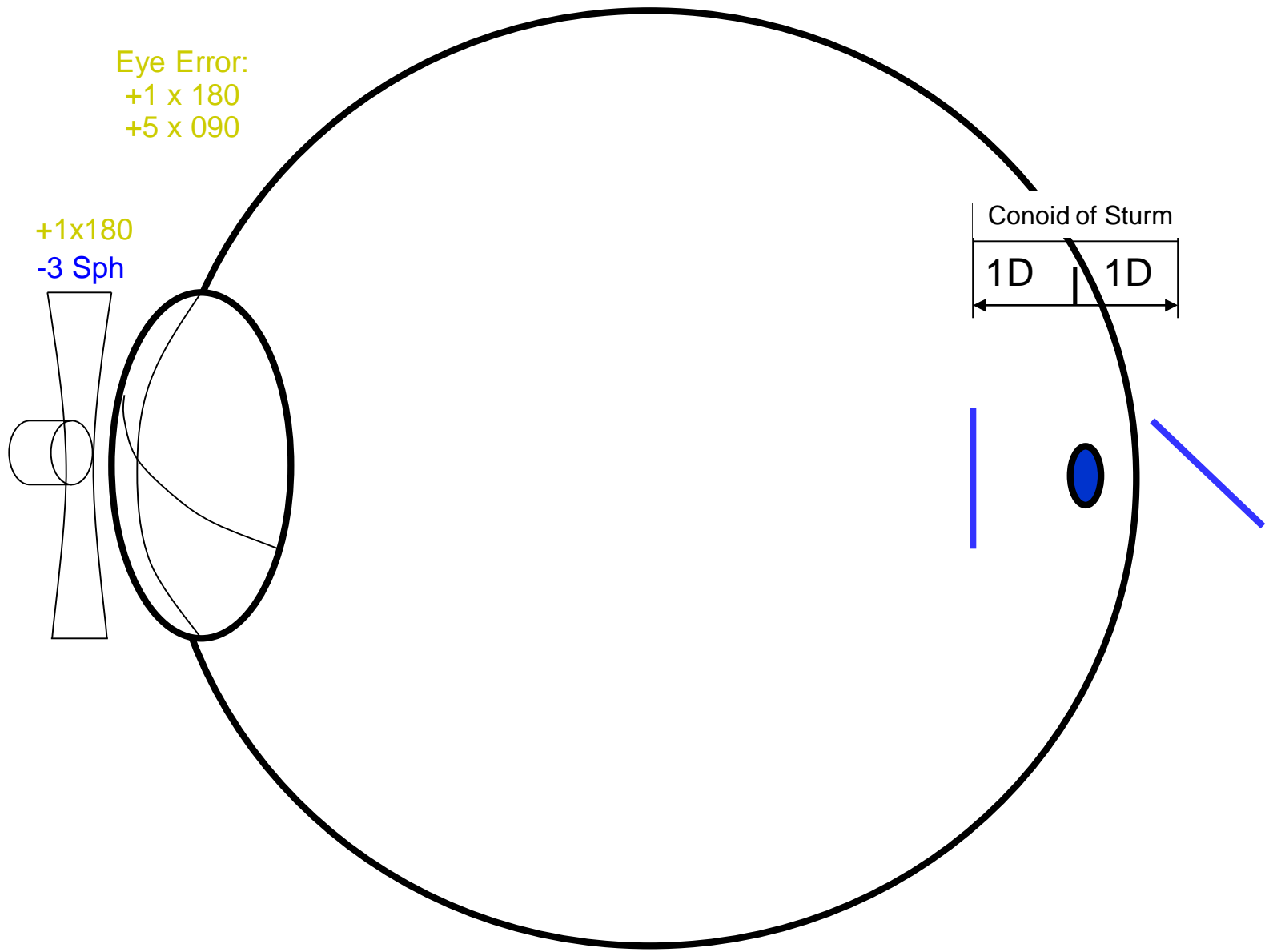




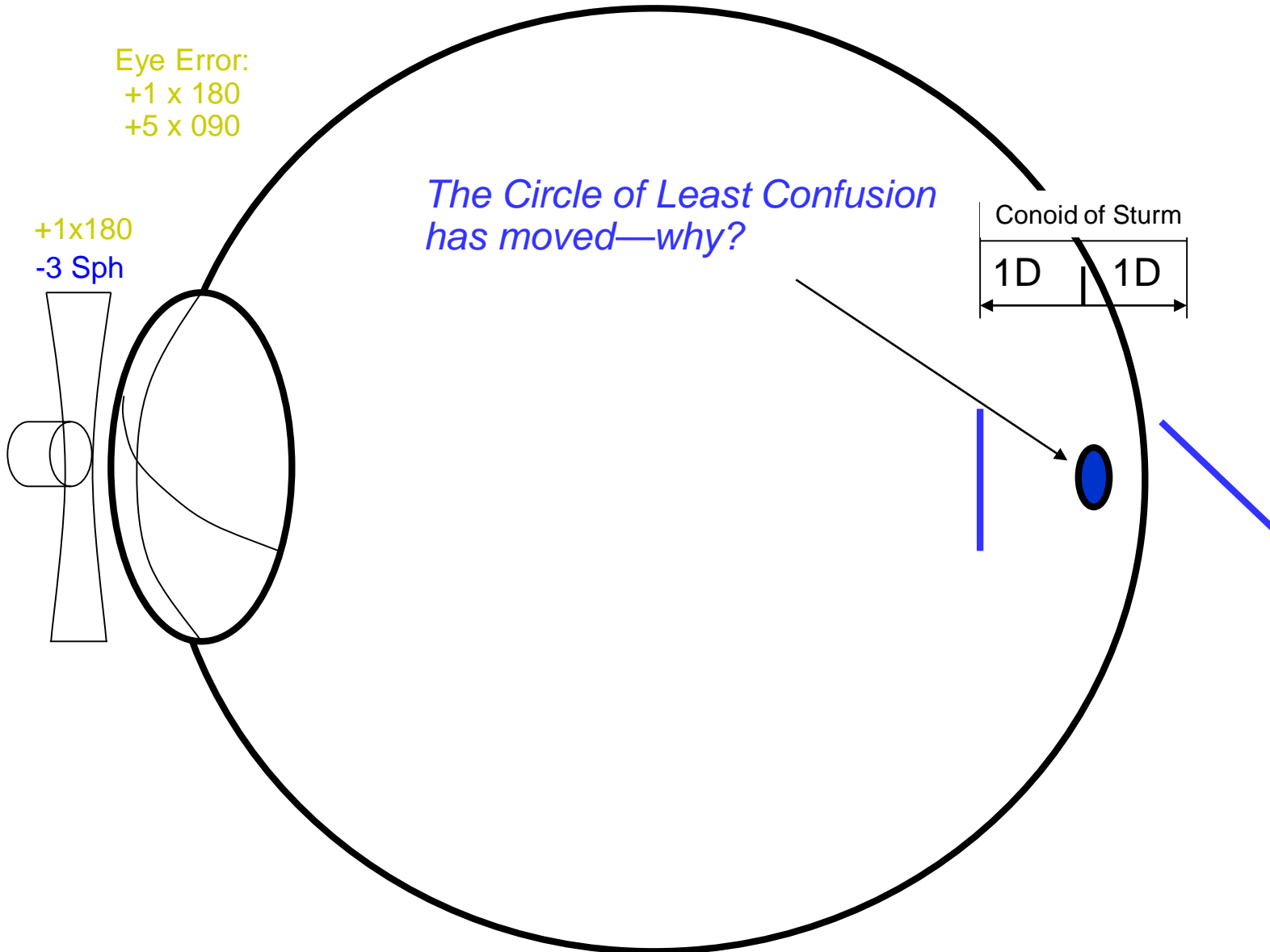
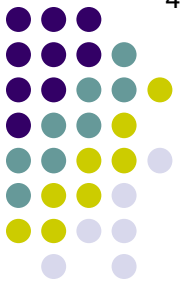
Astigmatic Correction: *Jackson Cross*

Eye Error:
+1 x 180
+5 x 090

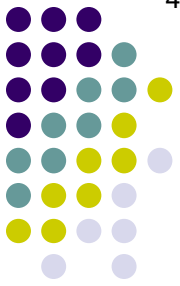
+1x180
-3 Sph



Astigmatic Correction: *Jackson Cross*

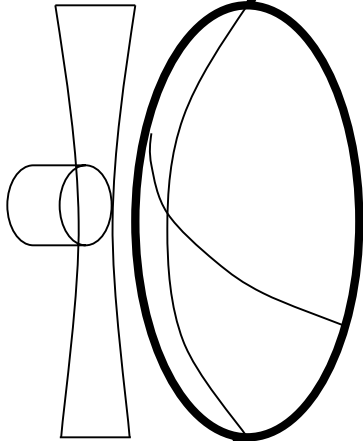


Astigmatic Correction: *Jackson Cross*



Eye Error:
 $+1 \times 180$
 $+5 \times 090$

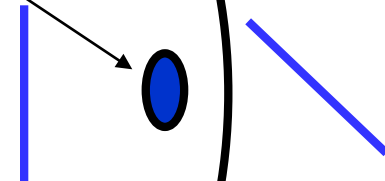
$+1 \times 180$
 -3 Sph



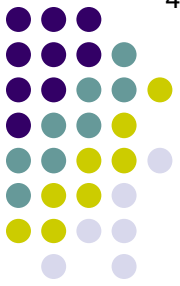
*The Circle of Least Confusion
 has moved—why?*

Because adding $+1 \times 180$
 changed the S.E. of the lenses
 before the eye from -3 to -2.50 .

Conoid of Sturm

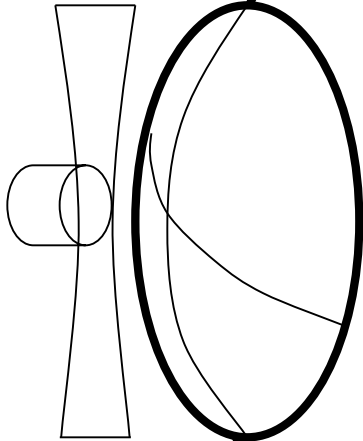


Astigmatic Correction: *Jackson Cross*



Eye Error:
+1 x 180
+5 x 090

+1x180
-3 Sph



The Circle of Least Confusion has moved—why?

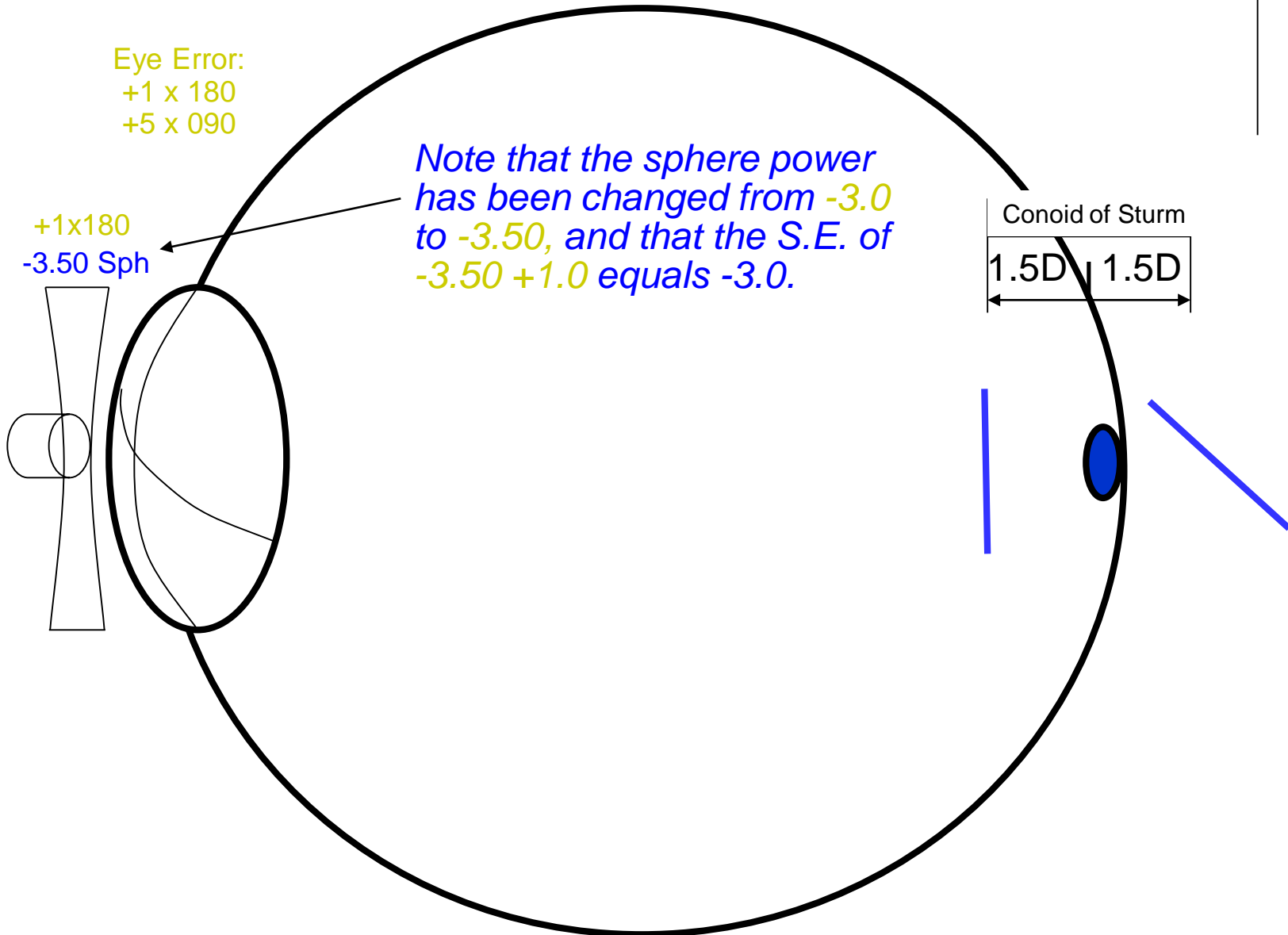
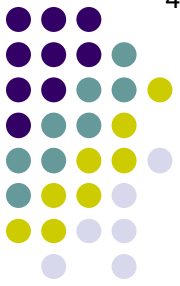
Conoid of Sturm



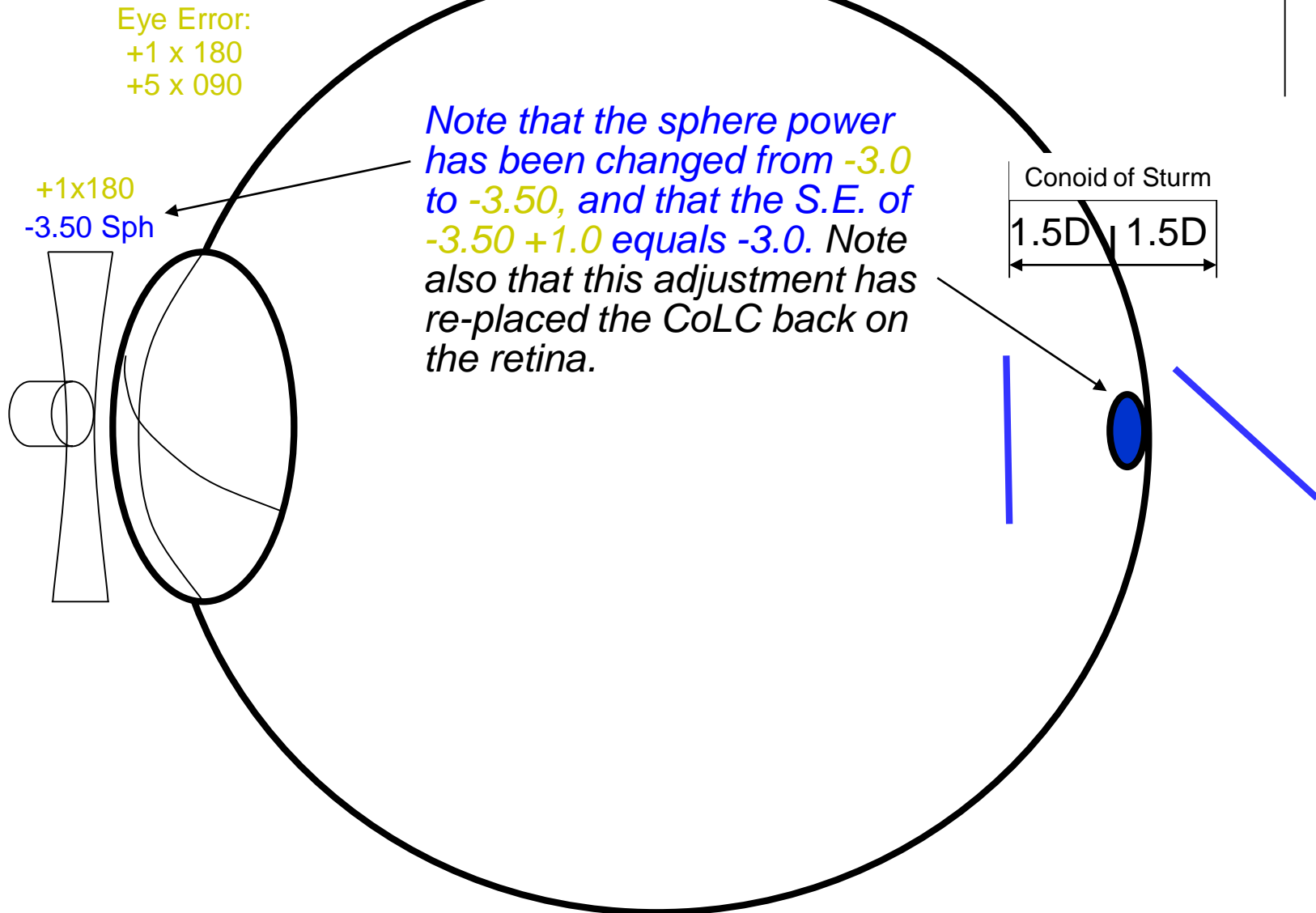
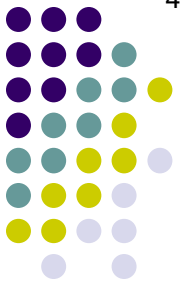
Because adding +1 x 180 changed the S.E. of the lenses before the eye from -3 to -2.50.

To keep the Circle on the retina, the sphere power must be adjusted to keep the total S.E. at -3.

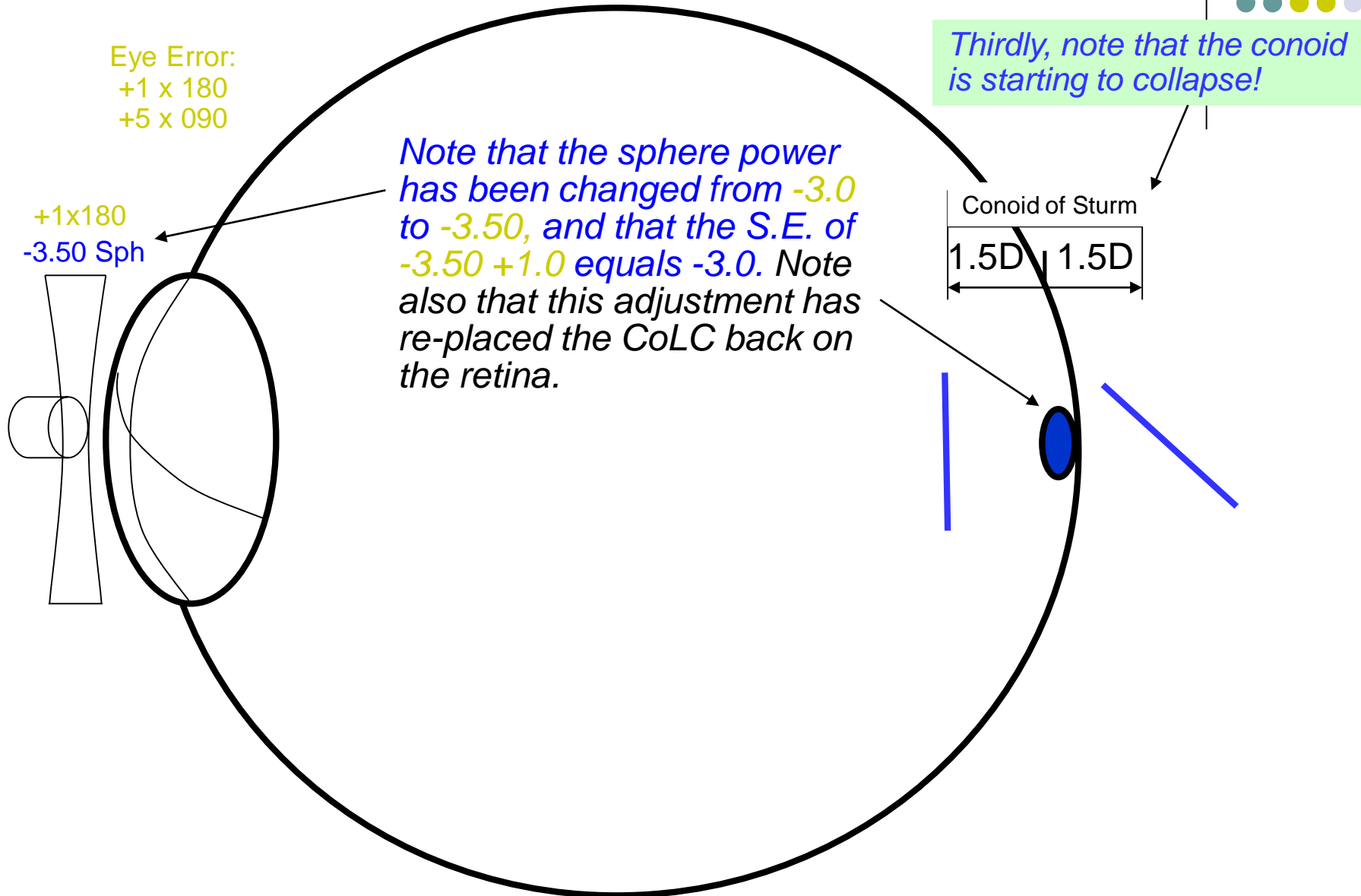
Astigmatic Correction: *Jackson Cross*

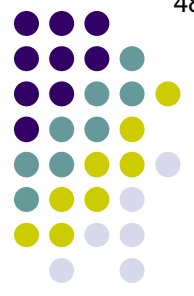


Astigmatic Correction: *Jackson Cross*



Astigmatic Correction: Jackson Cross

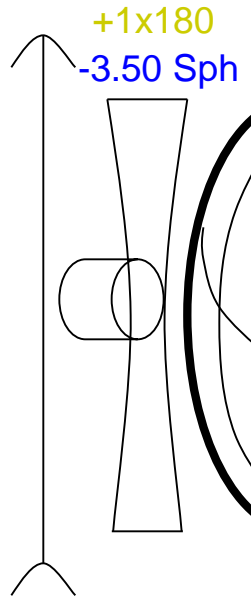




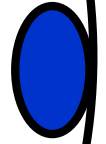
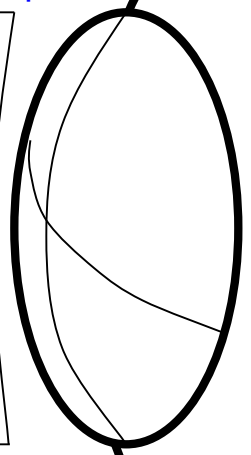
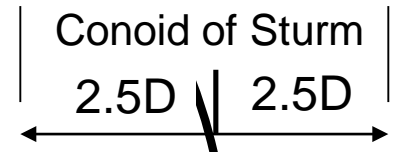
Astigmatic Correction: *Jackson Cross*

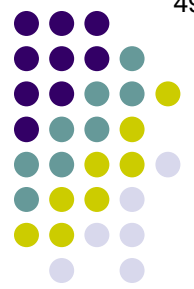
Eye Error:
+1 x 180
+5 x 090

Reintroduction of the cross
in this orientation moves the
focal lines **farther apart**.



+1x090
-1x180
↑
Jackson Cross



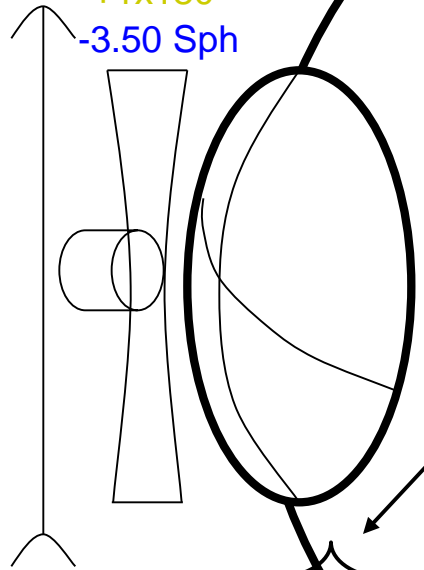


Astigmatic Correction: Jackson Cross

Eye Error:
+1 x 180
+5 x 090

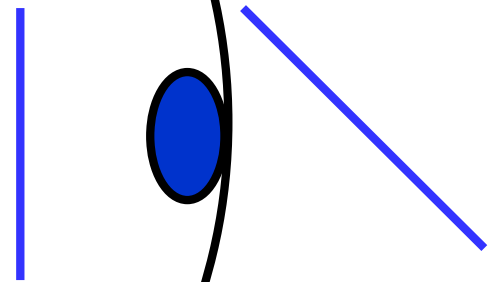
Reintroduction of the cross
in this orientation moves the
focal lines **farther apart**.

+1x180
-3.50 Sph

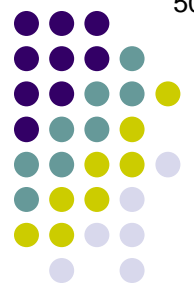


(Here's why)

Conoid of Sturm
2.5D | 2.5D



$$\begin{array}{r}
 +1 \times 090 \\
 -1 \times 180 \\
 \uparrow \\
 \text{Jackson} \\
 \text{Cross}
 \end{array}
 +
 \begin{array}{r}
 +5 \times 090 \\
 +2 \times 180 \\
 \uparrow \\
 \text{Eye error} \\
 \text{cylinders} \\
 + \\
 \text{corrective} \\
 \text{cylinder}
 \end{array}
 =
 \begin{array}{r}
 +6 \times 090 \\
 +1 \times 180 \\
 \uparrow \\
 \text{Total error} \\
 \text{power}
 \end{array}$$

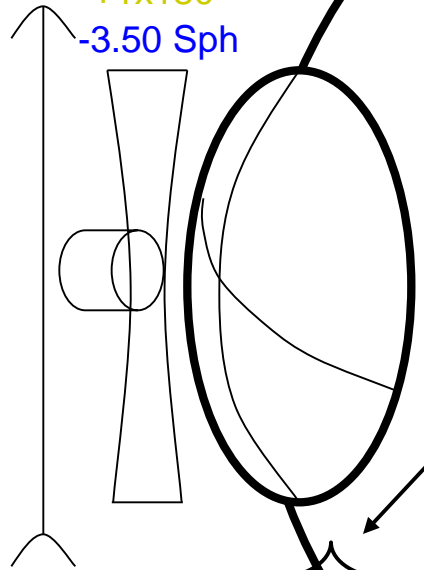


Astigmatic Correction: Jackson Cross

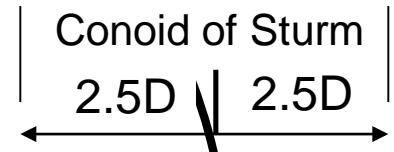
Eye Error:
+1 x 180
+5 x 090

Reintroduction of the cross
in this orientation moves the
focal lines **farther apart**.

+1x180
-3.50 Sph



(Here's why)



$$\begin{array}{r}
 +1 \times 090 \\
 -1 \times 180 \\
 \hline
 \end{array}
 +
 \begin{array}{r}
 +5 \times 090 \\
 +2 \times 180 \\
 \hline
 \end{array}
 =
 \begin{array}{r}
 +6 \times 090 \\
 +1 \times 180 \\
 \hline
 \end{array}$$

Jackson Cross Eye error cylinders + corrective cylinder Total error power

Note the conoid is now five diopters wide [(+6) - (+1) = 5], 2D wider than it was before this latest change.



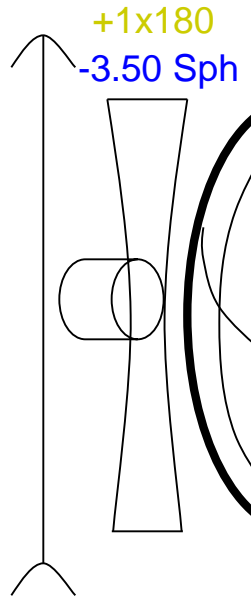
Astigmatic Correction: *Jackson Cross*

Eye Error:
+1 x 180
+5 x 090

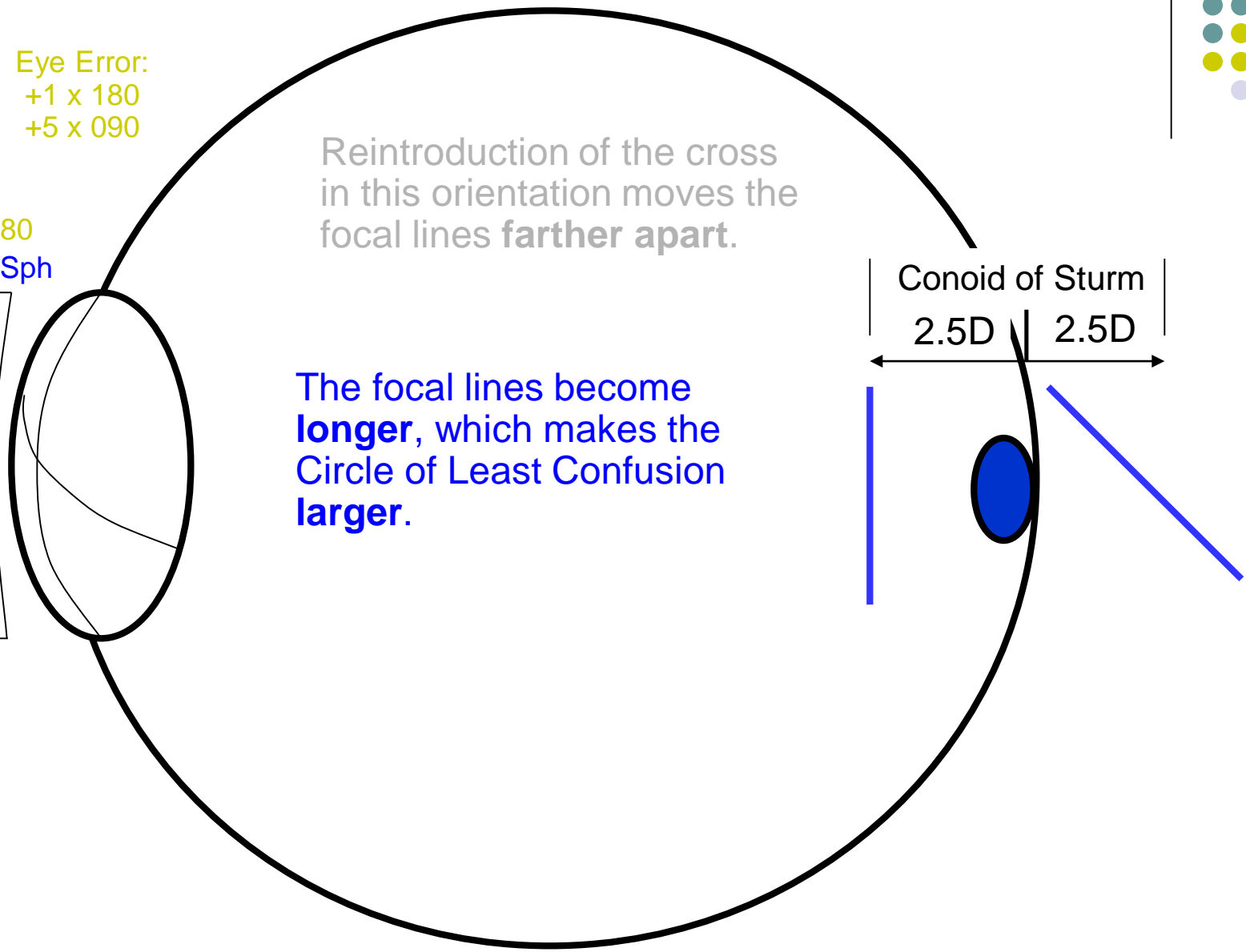
Reintroduction of the cross in this orientation moves the focal lines **farther apart**.

The focal lines become **longer**, which makes the Circle of Least Confusion **larger**.

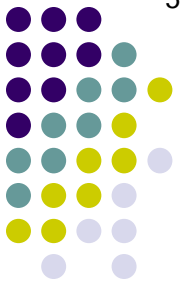
Conoid of Sturm
2.5D | 2.5D



+1x090
-1x180
↑
Jackson Cross



Astigmatic Correction: *Jackson Cross*



Eye Error:
+1 x 180
+5 x 090

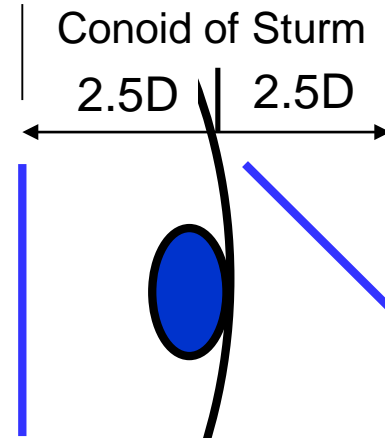
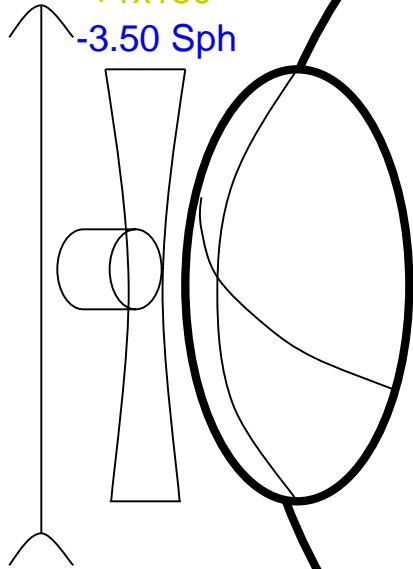
Reintroduction of the cross
in this orientation moves the
focal lines **farther apart**.

The focal lines become
longer, which makes the
Circle of Least Confusion
larger.

Because the Circle of Least
Confusion is larger, the image
seems **more blurry** to the patient.

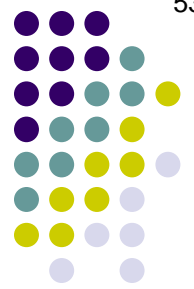
Conoid of Sturm
2.5D | 2.5D

+1x180
-3.50 Sph



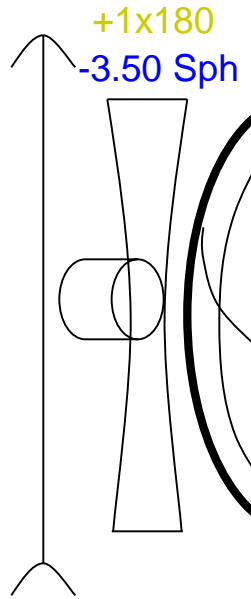
+1x090
-1x180

↑
*Jackson
Cross*



Astigmatic Correction: *Jackson Cross*

Eye Error:
+1 x 180
+5 x 090



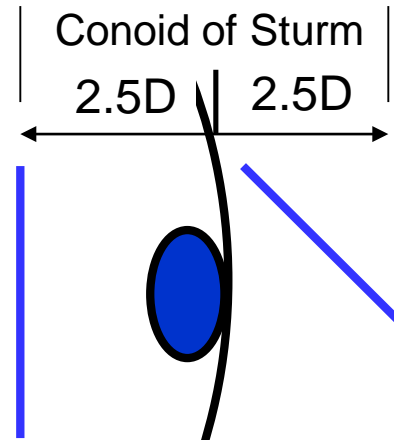
+1x090
-1x180
↑
Jackson Cross

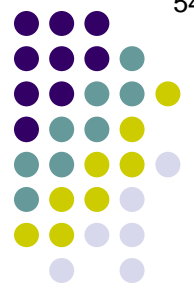
Reintroduction of the cross in this orientation moves the focal lines **farther apart**.

The focal lines become **longer**, which makes the Circle of Least Confusion **larger**.

Because the Circle of Least Confusion is larger, the image seems **more blurry** to the patient.

Flip the Jackson cross.

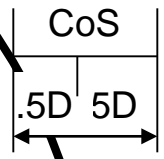
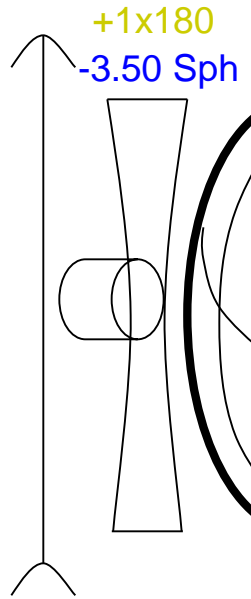




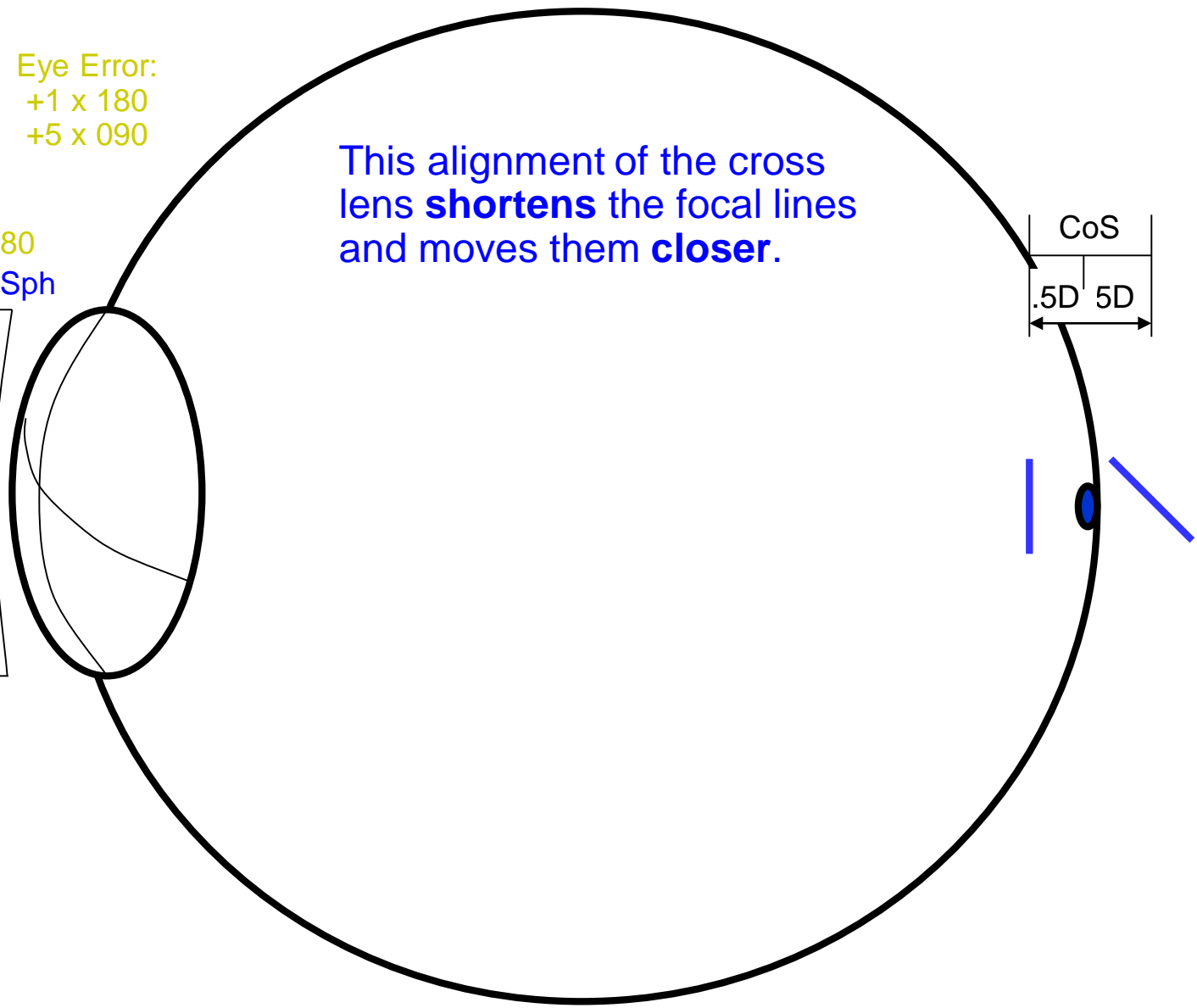
Astigmatic Correction: *Jackson Cross*

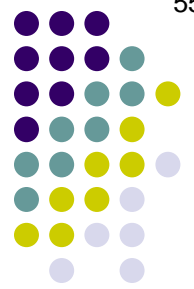
Eye Error:
+1 x 180
+5 x 090

This alignment of the cross lens **shortens** the focal lines and moves them **closer**.



-1x090
+1x180
↑
Jackson Cross



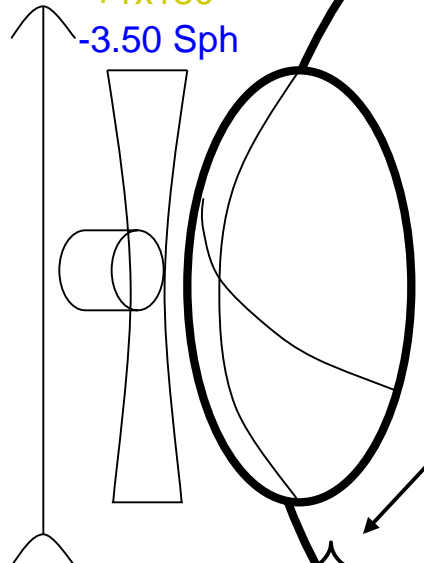


Astigmatic Correction: Jackson Cross

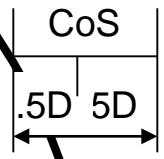
Eye Error:
+1 x 180
+5 x 090

This alignment of the cross lens **shortens** the focal lines and moves them **closer**.

+1x180
-3.50 Sph

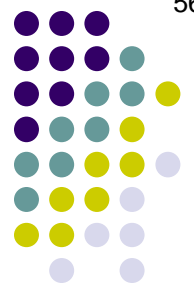


(Here's why)



$$\begin{array}{r}
 -1 \times 090 \\
 +1 \times 180 \\
 \hline
 \end{array}
 +
 \begin{array}{r}
 +5 \times 090 \\
 +2 \times 180 \\
 \hline
 \end{array}
 =
 \begin{array}{r}
 +4 \times 090 \\
 +3 \times 180 \\
 \hline
 \end{array}$$

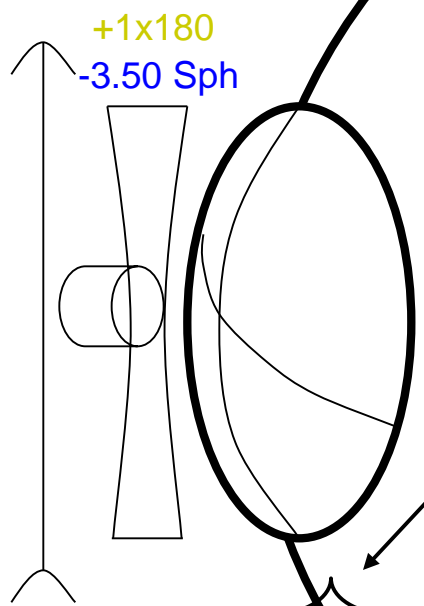
↑ Jackson Cross ↑ Eye error cylinders + corrective cylinder ↑ Total error power



Astigmatic Correction: *Jackson Cross*

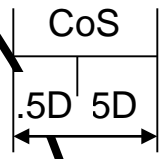
Eye Error:
+1 x 180
+5 x 090

This alignment of the cross lens **shortens** the focal lines and moves them **closer**.



+1x180
-3.50 Sph

(Here's why)



$$\begin{array}{r}
 -1 \times 090 \\
 +1 \times 180 \\
 \hline
 \end{array}
 +
 \begin{array}{r}
 +5 \times 090 \\
 +2 \times 180 \\
 \hline
 \end{array}
 =
 \begin{array}{r}
 +4 \times 090 \\
 +3 \times 180 \\
 \hline
 \end{array}$$

Jackson Cross Eye error cylinders + corrective cylinder Total error power

Note the conoid is now one diopter wide [(+4) - (+3) = 1], 4D less than it was before this latest change.

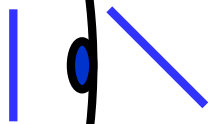
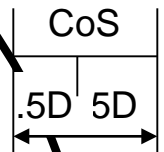
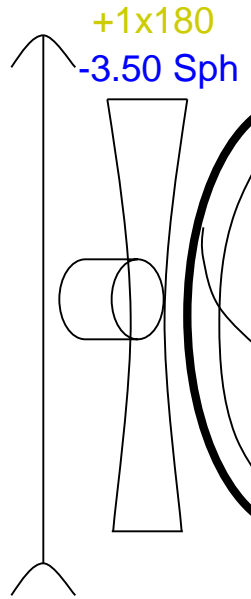


Astigmatic Correction: *Jackson Cross*

Eye Error:
+1 x 180
+5 x 090

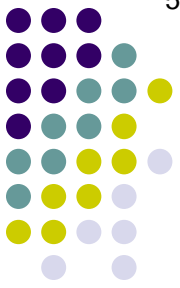
This alignment of the cross lens **shortens** the focal lines and moves them **closer**.

The shorter/closer focal lines make the Circle of Least Confusion **smaller**.



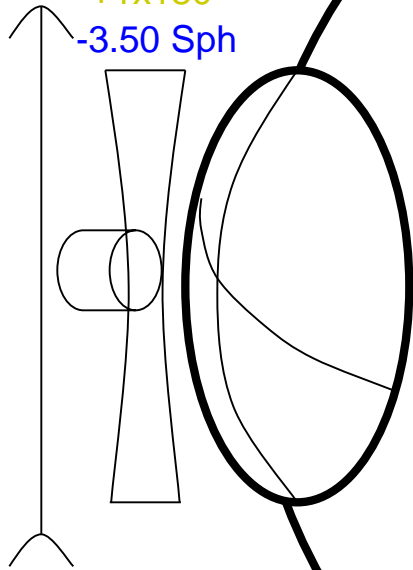
-1x090
+1x180
↑
Jackson Cross

Astigmatic Correction: *Jackson Cross*



Eye Error:
+1 x 180
+5 x 090

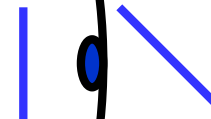
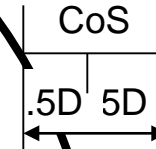
+1x180
-3.50 Sph



This alignment of the cross lens **shortens** the focal lines and moves them **closer**.

The shorter/closer focal lines make the Circle of Least Confusion **smaller**.

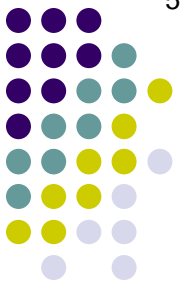
Because the Circle of Least Confusion is smaller, the image seems **less blurry** to the patient.



-1x090
+1x180

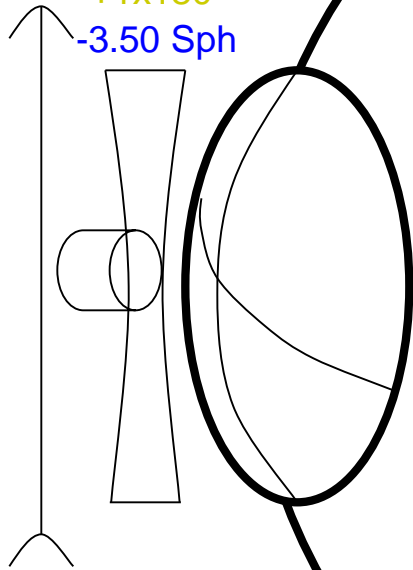
↑
Jackson Cross

Astigmatic Correction: *Jackson Cross*



Eye Error:
+1 x 180
+5 x 090

+1x180
-3.50 Sph

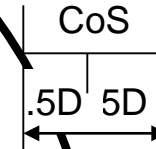


This alignment of the cross lens **shortens** the focal lines and moves them **closer**.

The shorter/closer focal lines make the Circle of Least Confusion **smaller**.

Because the Circle of Least Confusion is smaller, the image seems **less blurry** to the patient.

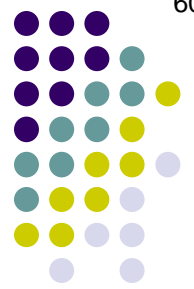
Because this is less blurry, +1 x 180 is added at the phoropter. (You remember to adjust the sphere.)



-1x090
+1x180

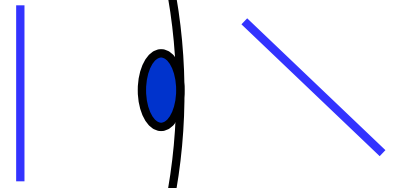
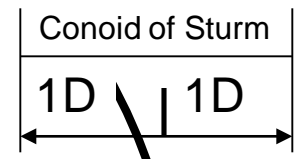
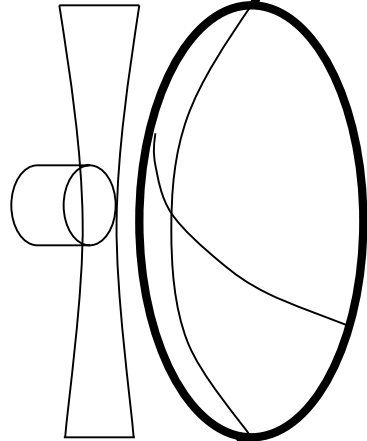
↑
Jackson Cross

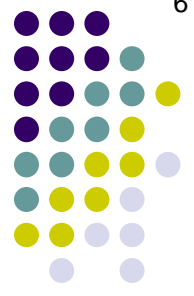
Astigmatic Correction: *Jackson Cross*



Eye Error:
+1 x 180
+5 x 090

+2x180
-4 Sph

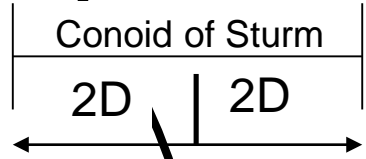




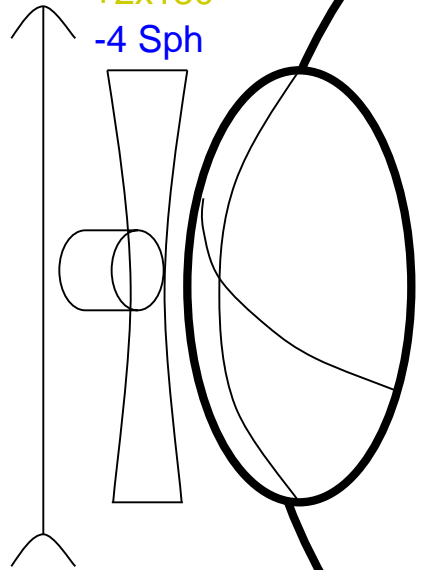
Astigmatic Correction: *Jackson Cross*

Eye Error:
+1 x 180
+5 x 090

Reintroduction of the cross
in this orientation moves the
focal lines farther apart.

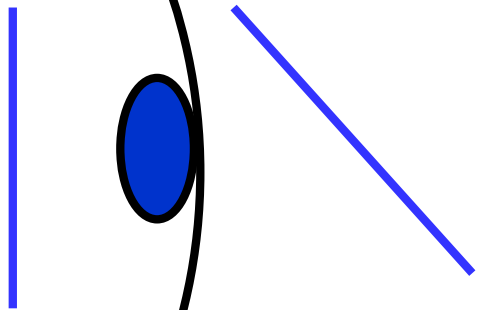


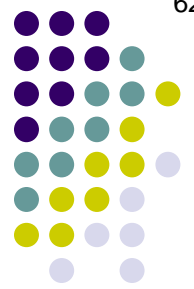
+2x180
-4 Sph



+1x090
-1x180

↑
Jackson Cross

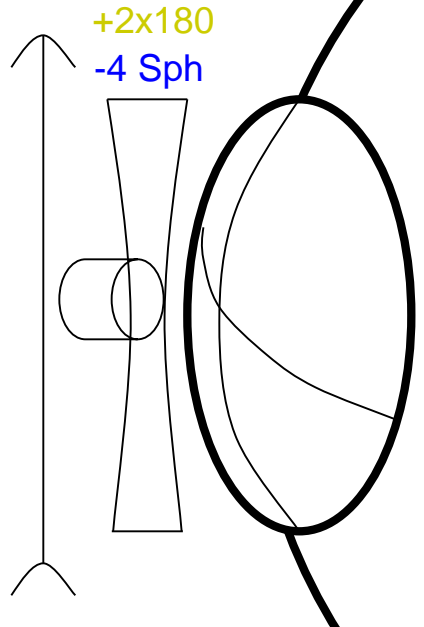
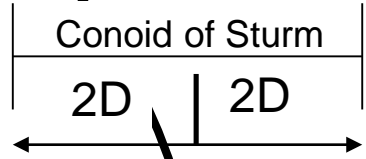




Astigmatic Correction: Jackson Cross

Eye Error:
+1 x 180
+5 x 090

Reintroduction of the cross
in this orientation moves the
focal lines farther apart.



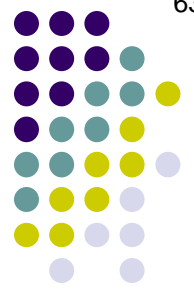
+2x180
-4 Sph

(Here's why)

$$\begin{array}{r}
 +1 \times 090 \\
 -1 \times 180 \\
 \uparrow \\
 \text{Jackson Cross}
 \end{array}
 +
 \begin{array}{r}
 +5 \times 090 \\
 +3 \times 180 \\
 \uparrow \\
 \text{Eye error cylinders} \\
 + \\
 \text{corrective cylinder}
 \end{array}
 =
 \begin{array}{r}
 +6 \times 090 \\
 +2 \times 180 \\
 \uparrow \\
 \text{Total error power}
 \end{array}$$

Eye error cylinders
+
corrective cylinder

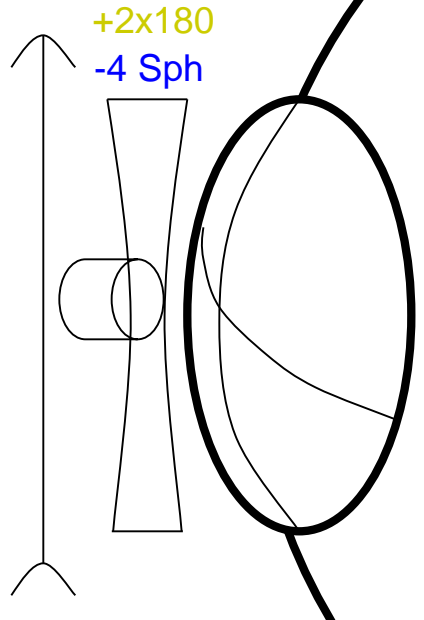
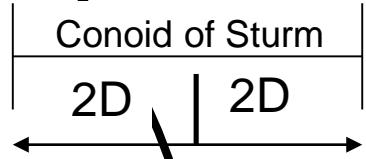
Total error power



Astigmatic Correction: Jackson Cross

Eye Error:
 +1 x 180
 +5 x 090

Reintroduction of the cross
 in this orientation moves the
 focal lines farther apart.

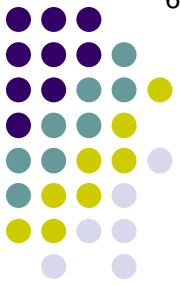


(Here's why)

Note the conoid is now four diopters wide again
 [(+4) - (+3) = 1], 3D wider than it was before
 this latest change.

$$\begin{array}{r}
 +1 \times 090 \\
 -1 \times 180 \\
 \uparrow \\
 \text{Jackson Cross}
 \end{array}
 +
 \begin{array}{r}
 +5 \times 090 \\
 +3 \times 180 \\
 \uparrow \\
 \text{Eye error cylinders} \\
 + \\
 \text{corrective cylinder}
 \end{array}
 =
 \begin{array}{r}
 +6 \times 090 \\
 +2 \times 180 \\
 \uparrow \\
 \text{Total error power}
 \end{array}$$

Astigmatic Correction: *Jackson Cross*



Eye Error:
+1 x 180
+5 x 090

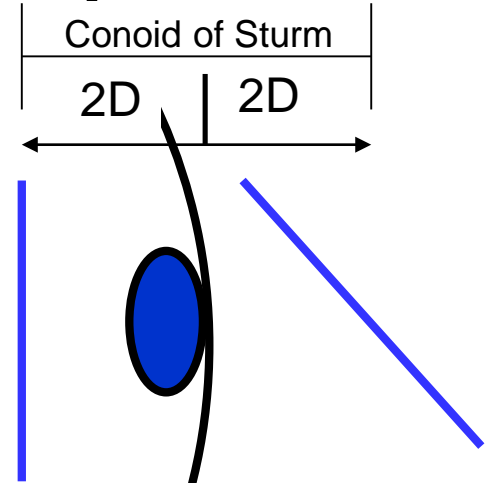
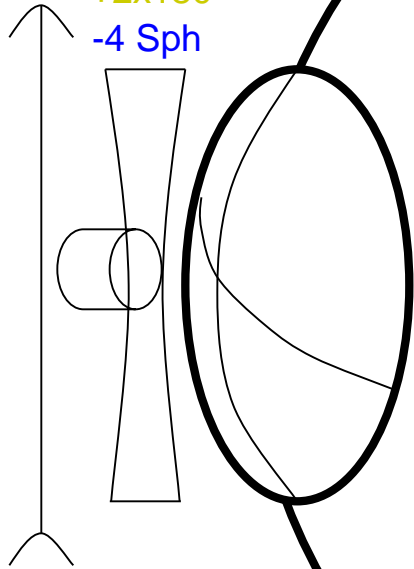
Reintroduction of the cross
in this orientation moves the
focal lines farther apart.

The focal lines become
longer, which makes the
Circle of Least Confusion
larger.

Conoid of Sturm

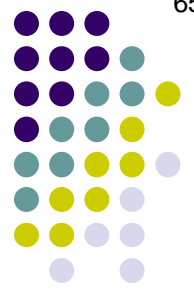
2D | 2D

+2x180
-4 Sph



+1x090
-1x180

↑
*Jackson
Cross*



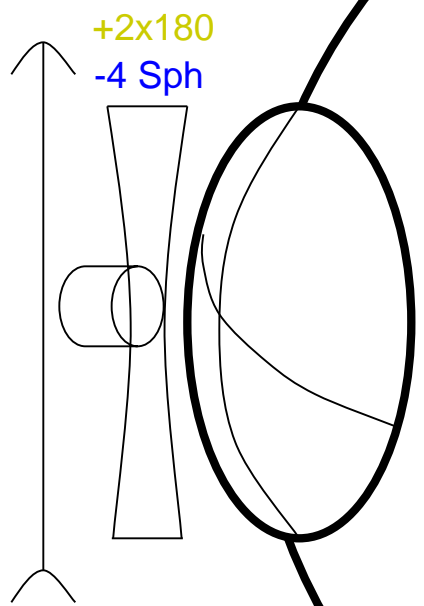
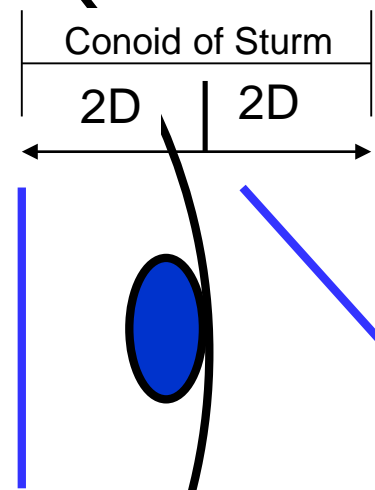
Astigmatic Correction: *Jackson Cross*

Eye Error:
+1 x 180
+5 x 090

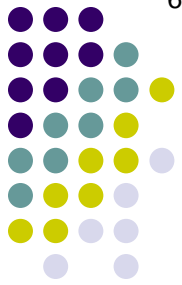
Reintroduction of the cross in this orientation moves the focal lines farther apart.

The focal lines become **longer**, which makes the Circle of Least Confusion **larger**.

Because the Circle of Least Confusion is larger, the image seems **more blurry** to the patient.



+1x090
-1x180
↑
Jackson Cross



Astigmatic Correction: *Jackson Cross*

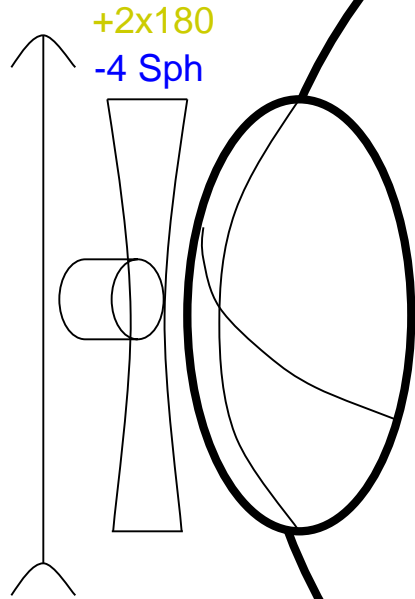
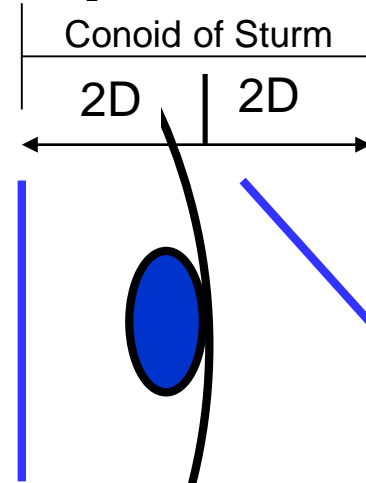
Eye Error:
+1 x 180
+5 x 090

Reintroduction of the cross in this orientation moves the focal lines farther apart.

The focal lines become **longer**, which makes the Circle of Least Confusion **larger**.

Because the Circle of Least Confusion is larger, the image seems **more blurry** to the patient.

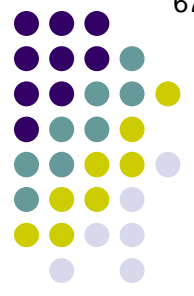
Flip the Jackson cross.



+2x180
-4 Sph

+1x090
-1x180

↑
Jackson Cross

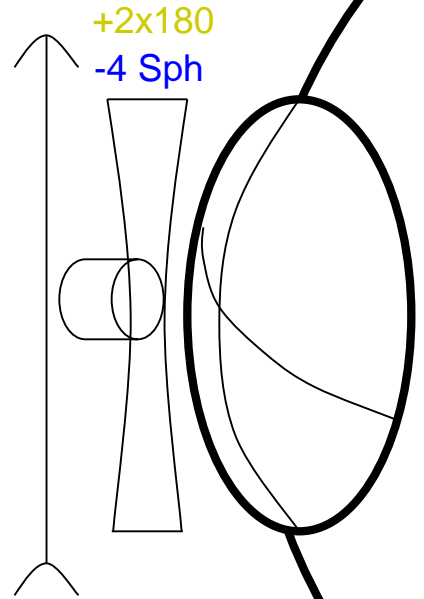


Astigmatic Correction: *Jackson Cross*

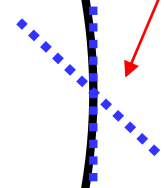
Eye Error:
+1 x 180
+5 x 090

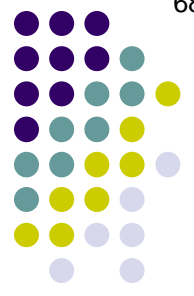
This alignment of the cross lens moves the focal lines closer together—in this case, collapsing the Conoid of Sturm.

(Misleading figure!)



-1x090
+1x180
↑
Jackson Cross



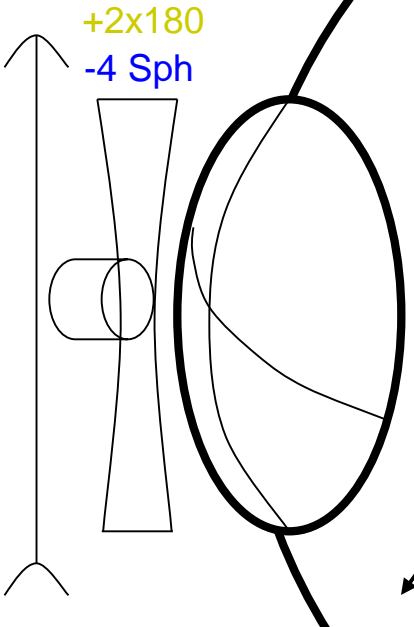


Astigmatic Correction: Jackson Cross

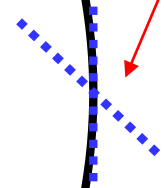
Eye Error:
+1 x 180
+5 x 090

This alignment of the cross lens moves the focal lines closer together—in this case, collapsing the Conoid of Sturm.

(Misleading figure!)

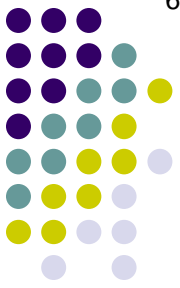


(Here's why)



$$\begin{array}{r}
 -1 \times 090 \\
 +1 \times 180 \\
 \uparrow \\
 \text{Jackson} \\
 \text{Cross}
 \end{array}
 +
 \begin{array}{r}
 +5 \times 090 \\
 +3 \times 180 \\
 \uparrow \\
 \text{Eye error} \\
 \text{cylinders} \\
 + \\
 \text{corrective} \\
 \text{cylinder}
 \end{array}
 =
 \begin{array}{r}
 +4 \times 090 \\
 +4 \times 180 \\
 \uparrow \\
 \text{Total error} \\
 \text{power}
 \end{array}$$

Astigmatic Correction: *Jackson Cross*

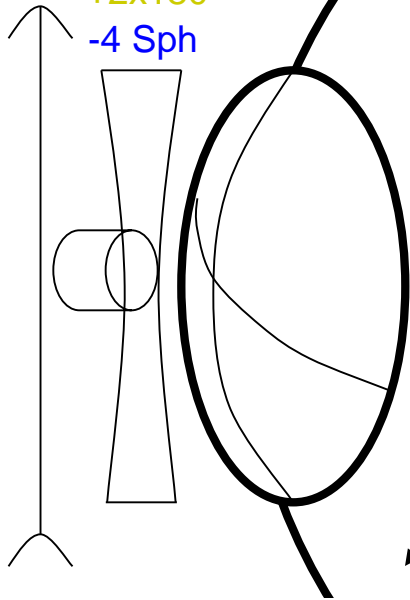


Eye Error:
+1 x 180
+5 x 090

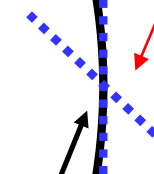
This alignment of the cross lens moves the focal lines closer together—in this case, collapsing the Conoid of Sturm.

(Misleading figure!)

+2x180
-4 Sph



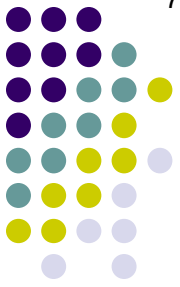
(Here's why)



Note the conoid is now collapsed!
[(+4) - (+4) = 0]

$$\begin{array}{r}
 -1 \times 090 \\
 +1 \times 180 \\
 \uparrow \\
 \text{Jackson} \\
 \text{Cross}
 \end{array}
 +
 \begin{array}{r}
 +5 \times 090 \\
 +3 \times 180 \\
 \uparrow \\
 \text{Eye error} \\
 \text{cylinders} \\
 + \\
 \text{corrective} \\
 \text{cylinder}
 \end{array}
 =
 \begin{array}{r}
 +4 \times 090 \\
 +4 \times 180 \\
 \uparrow \\
 \text{Total error} \\
 \text{power}
 \end{array}$$

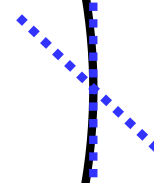
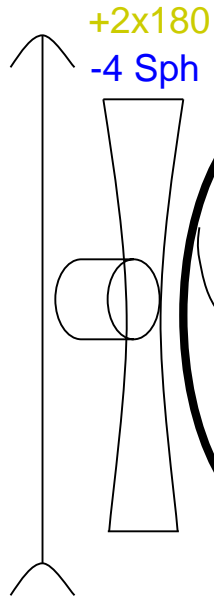
Astigmatic Correction: *Jackson Cross*

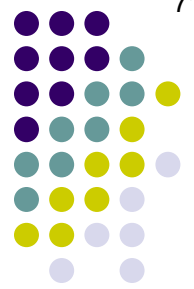


Eye Error:
 $+1 \times 180$
 $+5 \times 090$

This alignment of the cross lens moves the focal lines closer together—in this case, collapsing the Conoid of Sturm.

Because this is less blurry, $+1 \times 180$ is added at the phoropter. (You remember to adjust the sphere.)

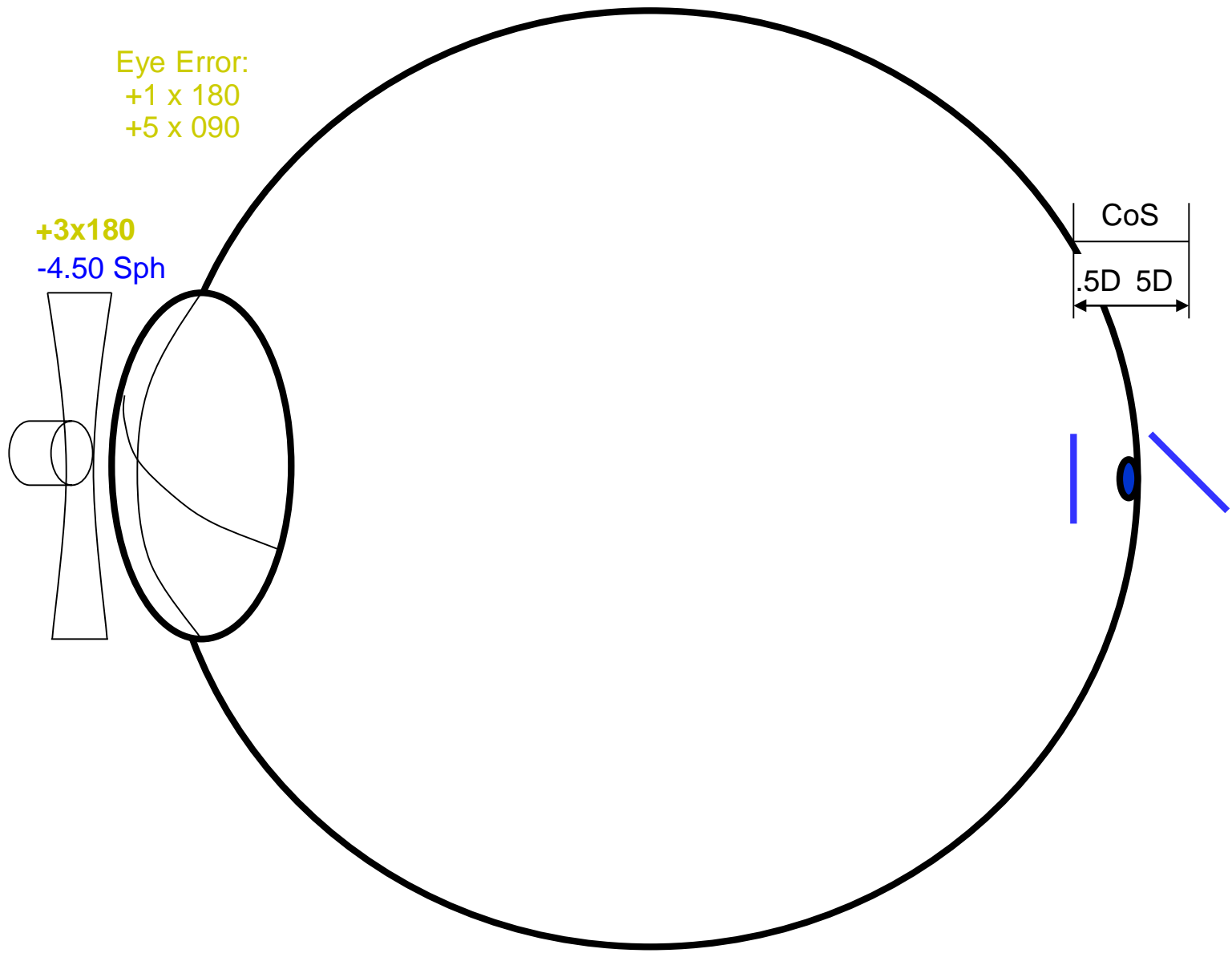


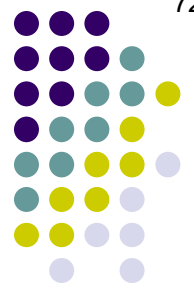


Astigmatic Correction: *Jackson Cross*

Eye Error:
+1 x 180
+5 x 090

+3x180
-4.50 Sph





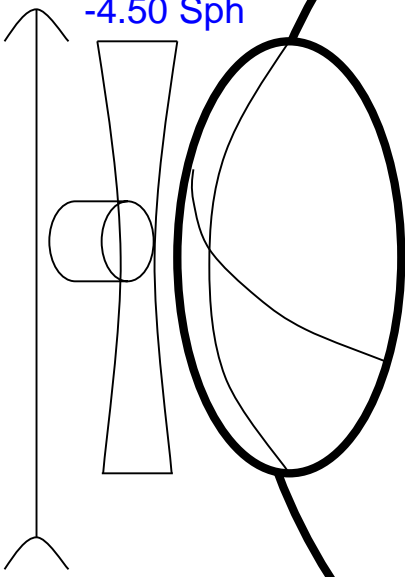
Astigmatic Correction: *Jackson Cross*

Eye Error:
+1 x 180
+5 x 090

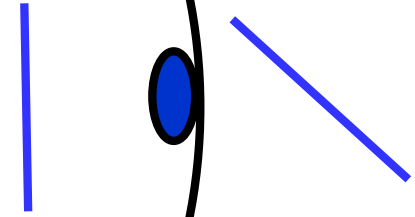
Reintroduction of the cross
in this orientation moves the
focal lines farther apart.

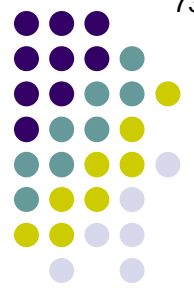
Conoid of Sturm
1.5D 1.5D

+3x180
-4.50 Sph



+1x090
-1x180
↑
Jackson Cross





Astigmatic Correction: *Jackson Cross*

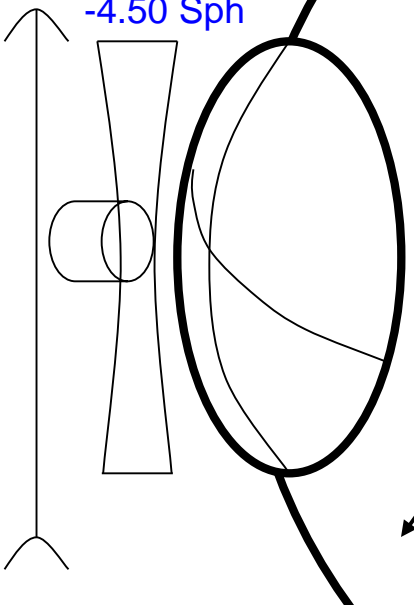
Eye Error:
+1 x 180
+5 x 090

Reintroduction of the cross
in this orientation moves the
focal lines farther apart.

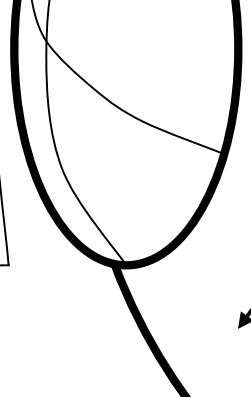
Conoid of Sturm
1.5D | 1.5D

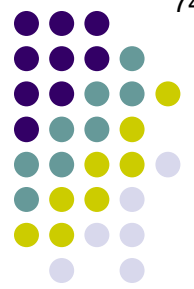
(Here's why)

+3x180
-4.50 Sph



$$\begin{array}{r}
 +1 \times 090 \\
 -1 \times 180 \\
 \uparrow \\
 \text{Jackson} \\
 \text{Cross}
 \end{array}
 +
 \begin{array}{r}
 +5 \times 090 \\
 +4 \times 180 \\
 \uparrow \\
 \text{Eye error} \\
 \text{cylinders} \\
 + \\
 \text{corrective} \\
 \text{cylinder}
 \end{array}
 =
 \begin{array}{r}
 +6 \times 090 \\
 +3 \times 180 \\
 \uparrow \\
 \text{Total error} \\
 \text{power}
 \end{array}$$





Astigmatic Correction: Jackson Cross

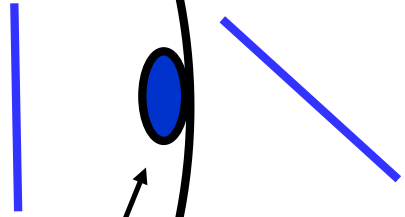
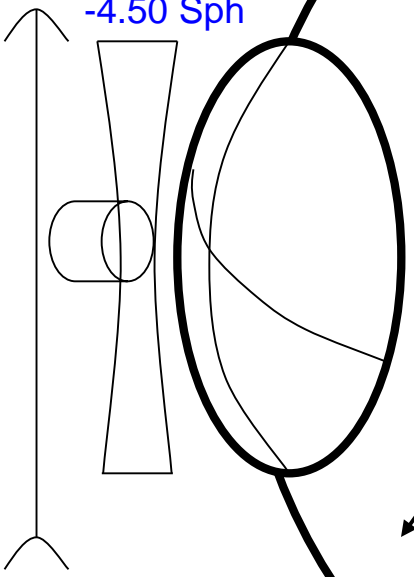
Eye Error:
+1 x 180
+5 x 090

Reintroduction of the cross
in this orientation moves the
focal lines farther apart.

Conoid of Sturm
1.5D 1.5D

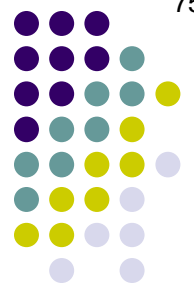
(Here's why)

+3x180
-4.50 Sph



$$\begin{array}{r}
 +1 \times 090 \\
 -1 \times 180 \\
 \uparrow \\
 \text{Jackson} \\
 \text{Cross}
 \end{array}
 +
 \begin{array}{r}
 +5 \times 090 \\
 +4 \times 180 \\
 \uparrow \\
 \text{Eye error} \\
 \text{cylinders} \\
 + \\
 \text{corrective} \\
 \text{cylinder}
 \end{array}
 =
 \begin{array}{r}
 +6 \times 090 \\
 +3 \times 180 \\
 \uparrow \\
 \text{Total error} \\
 \text{power}
 \end{array}$$

Note the conoid is now three diopters wide [(+6) - (+3) = 3], 2D wider than it was before this latest change.



Astigmatic Correction: *Jackson Cross*

Eye Error:
+1 x 180
+5 x 090

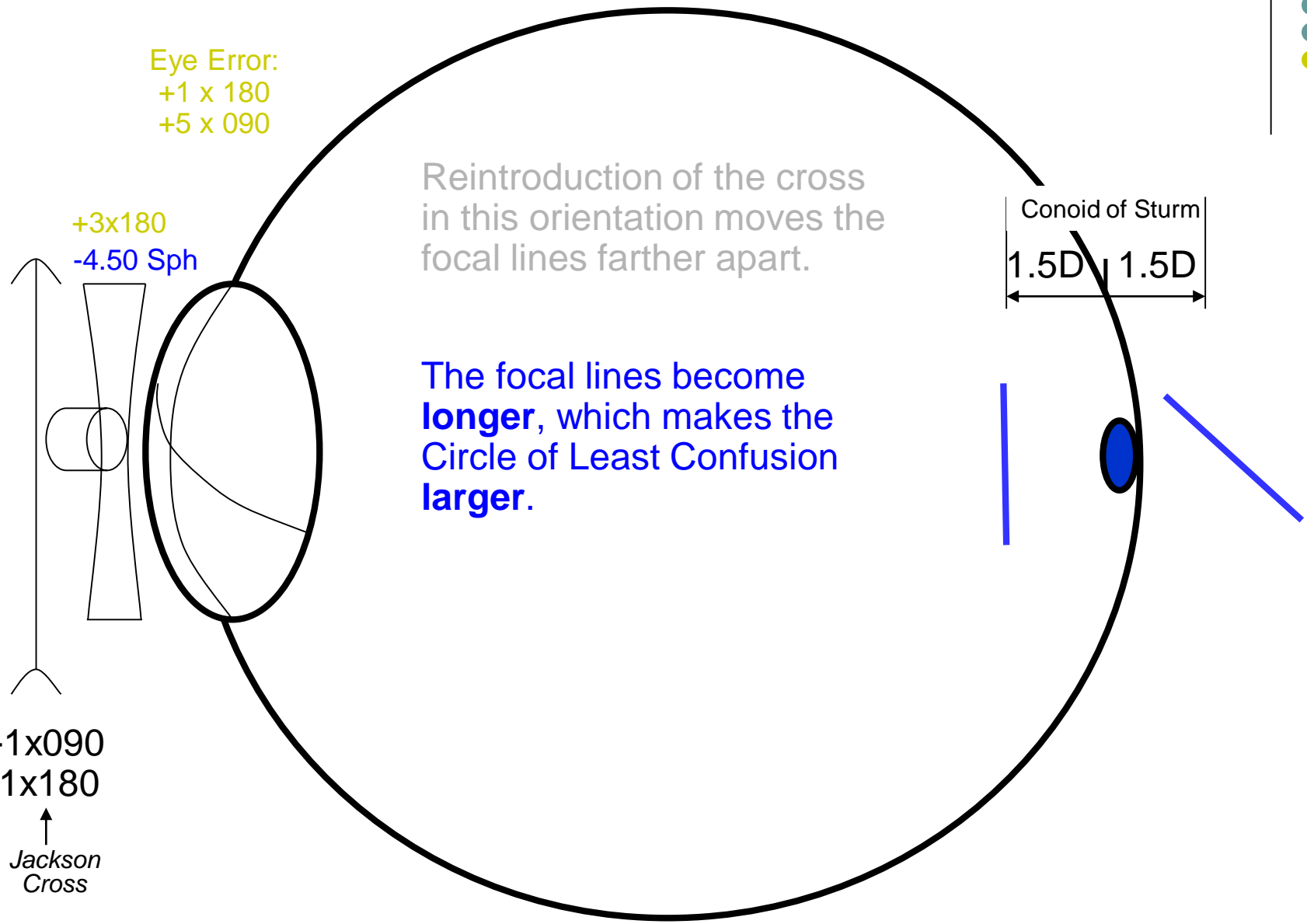
+3x180
-4.50 Sph

Reintroduction of the cross in this orientation moves the focal lines farther apart.

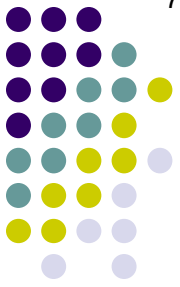
The focal lines become **longer**, which makes the Circle of Least Confusion **larger**.

Conoid of Sturm
1.5D | 1.5D

+1x090
-1x180
↑
Jackson Cross



Astigmatic Correction: *Jackson Cross*



Eye Error:
+1 x 180
+5 x 090

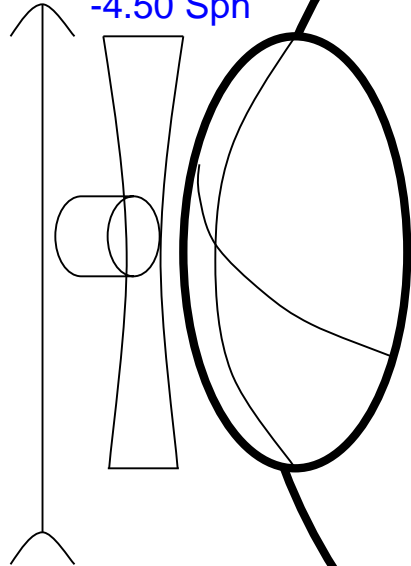
+3x180
-4.50 Sph

Reintroduction of the cross in this orientation moves the focal lines farther apart.

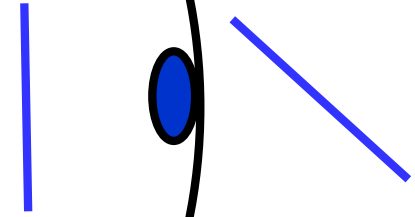
The focal lines become **longer**, which makes the Circle of Least Confusion **larger**.

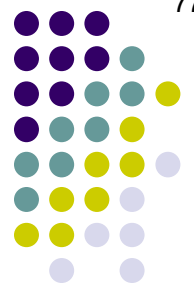
Because the Circle of Least Confusion is larger, the image seems **more blurry** to the patient.

Conoid of Sturm
1.5D | 1.5D



+1x090
-1x180
↑
Jackson Cross

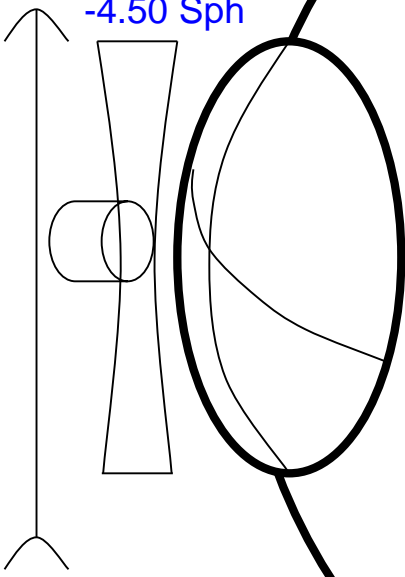




Astigmatic Correction: Jackson Cross

Eye Error:
+1 x 180
+5 x 090

+3x180
-4.50 Sph

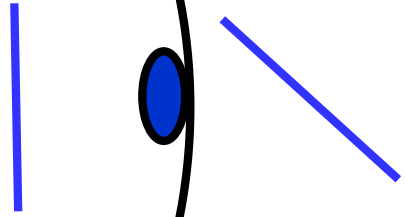
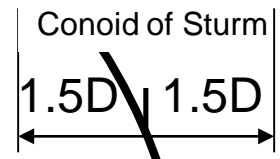


Reintroduction of the cross in this orientation moves the focal lines farther apart.

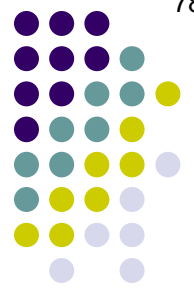
The focal lines become **longer**, which makes the Circle of Least Confusion **larger**.

Because the Circle of Least Confusion is larger, the image seems **more blurry** to the patient.

Flip the Jackson cross.



+1x090
-1x180
↑
Jackson Cross

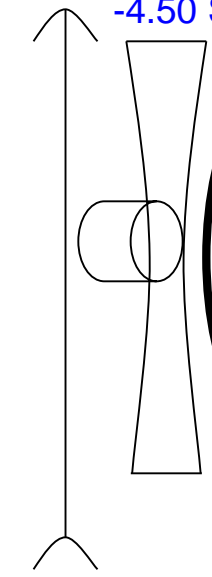


Astigmatic Correction: *Jackson Cross*

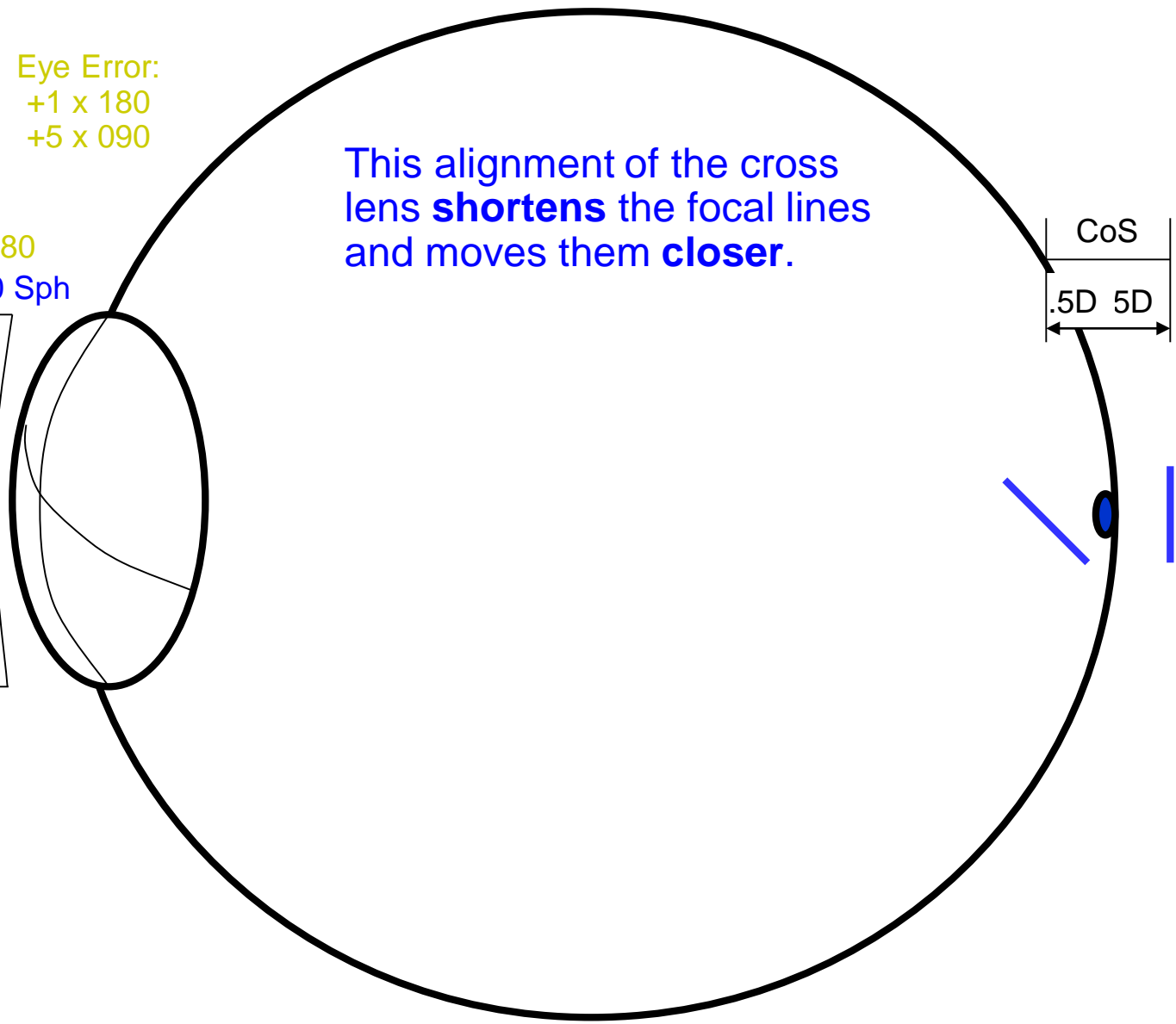
Eye Error:
+1 x 180
+5 x 090

This alignment of the cross lens **shortens** the focal lines and moves them **closer**.

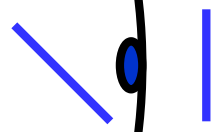
+3x180
-4.50 Sph

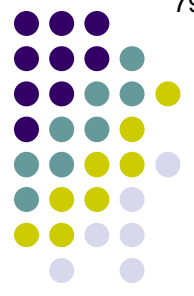


-1x090
+1x180
↑
Jackson Cross



CoS
.5D 5D



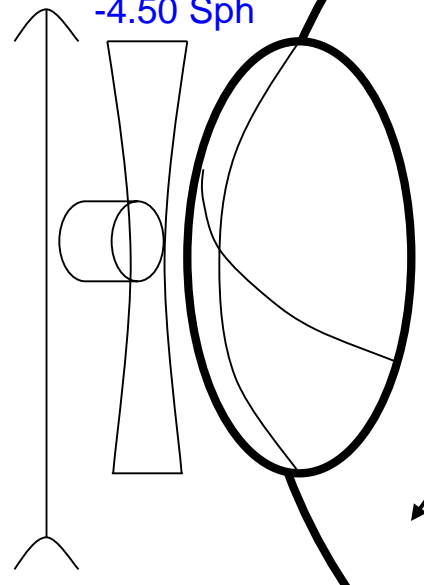


Astigmatic Correction: Jackson Cross

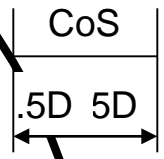
Eye Error:
+1 x 180
+5 x 090

This alignment of the cross lens **shortens** the focal lines and moves them **closer**.

+3x180
-4.50 Sph



(Here's why)



$$\begin{matrix} -1 \times 090 \\ +1 \times 180 \end{matrix} + \begin{matrix} +5 \times 090 \\ +4 \times 180 \end{matrix} = \begin{matrix} +4 \times 090 \\ +5 \times 180 \end{matrix}$$

Jackson Cross

Eye error cylinders + corrective cylinder

Total error power



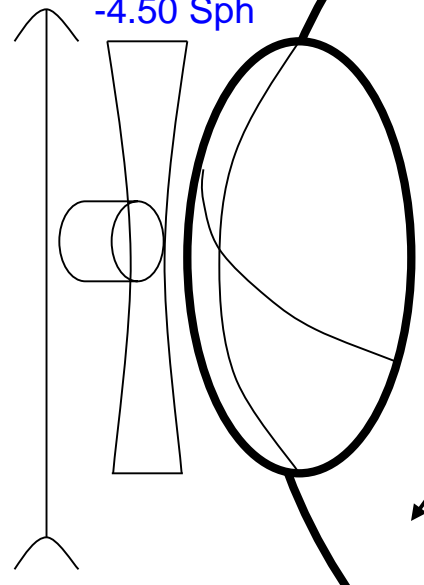


Astigmatic Correction: Jackson Cross

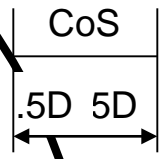
Eye Error:
+1 x 180
+5 x 090

This alignment of the cross lens **shortens** the focal lines and moves them **closer**.

+3x180
-4.50 Sph



(Here's why)



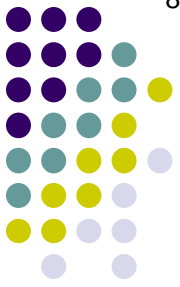
$$\begin{matrix} -1 \times 090 \\ +1 \times 180 \end{matrix} + \begin{matrix} +5 \times 090 \\ +4 \times 180 \end{matrix} = \begin{matrix} +4 \times 090 \\ +5 \times 180 \end{matrix}$$

Jackson Cross Eye error cylinders + corrective cylinder Total error power

Note the conoid is now one diopter wide [(+5) - (+4) = 1], 2D less than it was before this latest change.

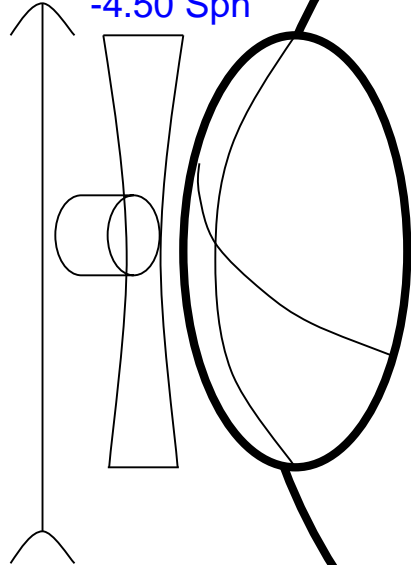


Astigmatic Correction: *Jackson Cross*



Eye Error:
+1 x 180
+5 x 090

+3x180
-4.50 Sph



This alignment of the cross lens **shortens** the focal lines and moves them **closer**.

Note also that the focal lines have *changed positions* (i.e., the horizontal line is now anterior, and the vertical line is posterior)

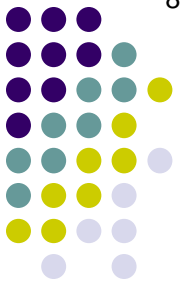
CoS
.5D 5D



+1x090
-1x180

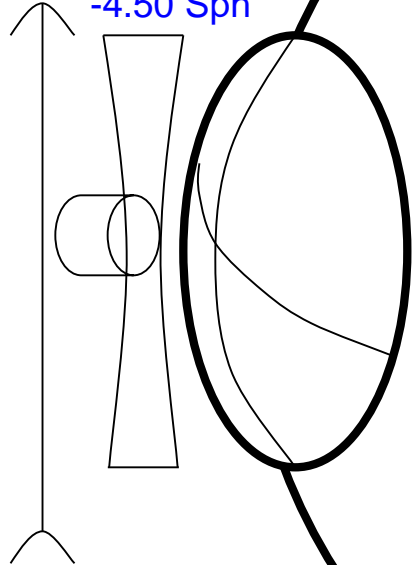
↑
Jackson Cross

Astigmatic Correction: *Jackson Cross*



Eye Error:
+1 x 180
+5 x 090

+3x180
-4.50 Sph



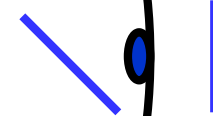
This alignment of the cross lens **shortens** the focal lines and moves them **closer**.

Note also that the focal lines have *changed positions* (i.e., the horizontal line is now anterior, and the vertical line is posterior)

This is indicated by the fact that the axis 180 cylindrical power is now (and for the first time) greater than that of the axis 090 cylinder.

+4 x 090
+5 x 180

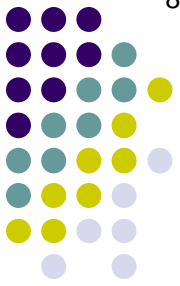
CoS
.5D 5D



+1x090
-1x180

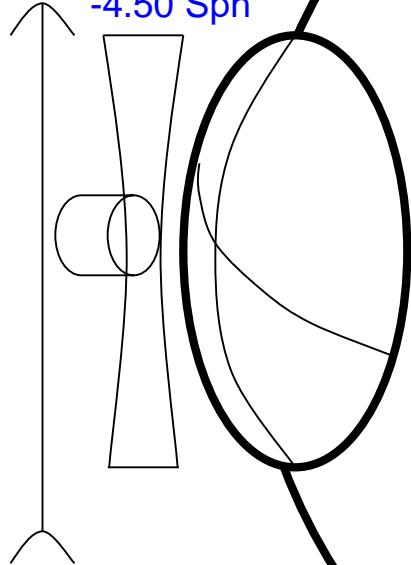
↑
Jackson Cross

Astigmatic Correction: *Jackson Cross*



Eye Error:
+1 x 180
+5 x 090

+3x180
-4.50 Sph



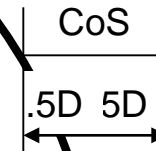
+1x090
-1x180

↑
*Jackson
Cross*

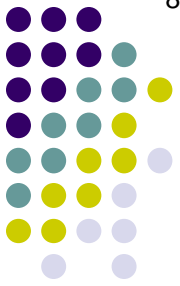
This alignment of the cross lens **shortens** the focal lines and moves them **closer**.

Note also that the focal lines have *changed positions* (i.e., the horizontal line is now anterior, and the vertical line is posterior)

The focal lines become **shorter**, which makes the Circle of Least Confusion **smaller**.

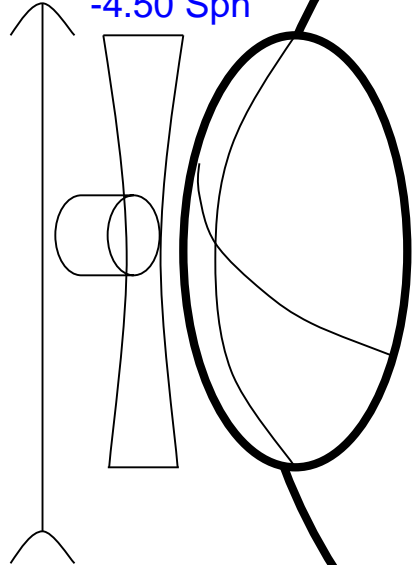


Astigmatic Correction: *Jackson Cross*



Eye Error:
+1 x 180
+5 x 090

+3x180
-4.50 Sph

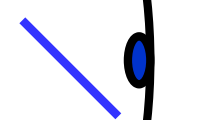
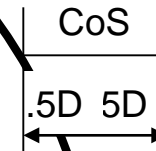


This alignment of the cross lens **shortens** the focal lines and moves them **closer**.

Note also that the focal lines have *changed positions* (i.e., the horizontal line is now anterior, and the vertical line is posterior)

The focal lines become **shorter**, which makes the Circle of Least Confusion **smaller**.

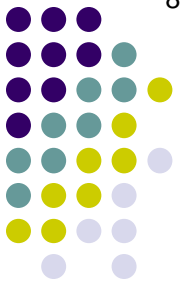
Because this is less blurry, +1 x 180 is added at the phoropter. (You remember to adjust the sphere.)



+1x090
-1x180

↑
Jackson Cross

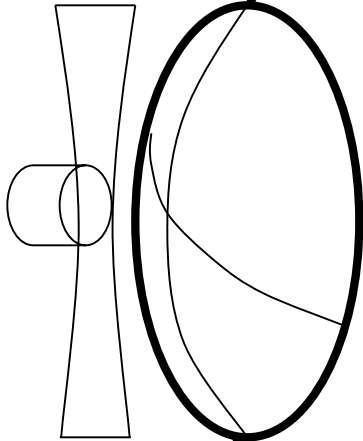
Astigmatic Correction: *Jackson Cross*



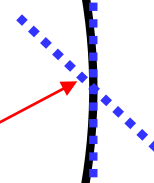
Eye Error:
+1 x 180
+5 x 090

The refractive error has been eliminated.

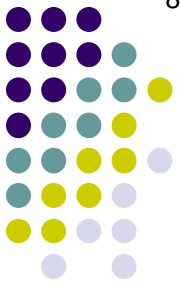
+4x180
-5 Sph



(Misleading figure!)



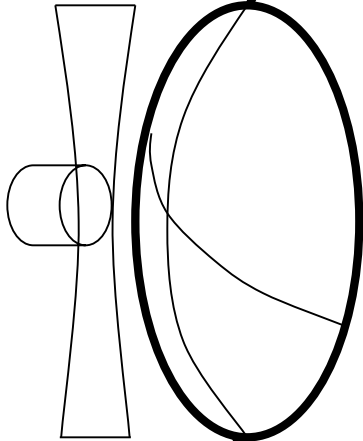
Astigmatic Correction: *Jackson Cross*



Eye Error:
+1 x 180
+5 x 090

The refractive error has been eliminated.

+4x180
-5 Sph



(Here's why)

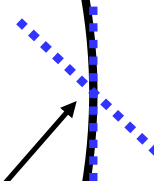
No Jackson cross lens

$$+5 \times 090 + 5 \times 180 = +5 \times 090 + 5 \times 180$$

Eye error cylinders
+
corrective cylinder

Total error power

Note the conoid is collapsed without the Jackson cross.
(Remember, the -5D sphere lens is pushing the collapsed conoid back onto the retina.)



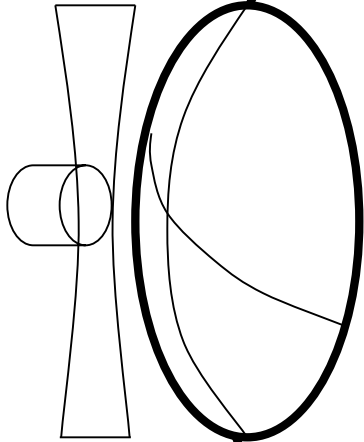
Astigmatic Correction: *Jackson Cross*



Eye Error:
+1 x 180
+5 x 090

The refractive error has been eliminated.

+4x180
-5 Sph



(Here's why)

No Jackson cross lens

$$+5 \times 090 + 5 \times 180 = +5 \times 090 + 5 \times 180$$

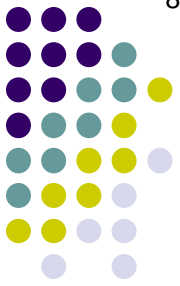
Eye error cylinders
+
corrective cylinder

Total error power

Note the conoid is collapsed without the Jackson cross. (Remember, the -5D sphere lens is pushing the collapsed conoid back onto the retina.)

To understand why, recall that we can think of any spherical lens as being composed of two cylindrical lenses oriented 90° apart. So, in this case, think of the -5D sphere lens as being composed of two -5D cylinders, one of which is at axis 090 and the other at axis 180.

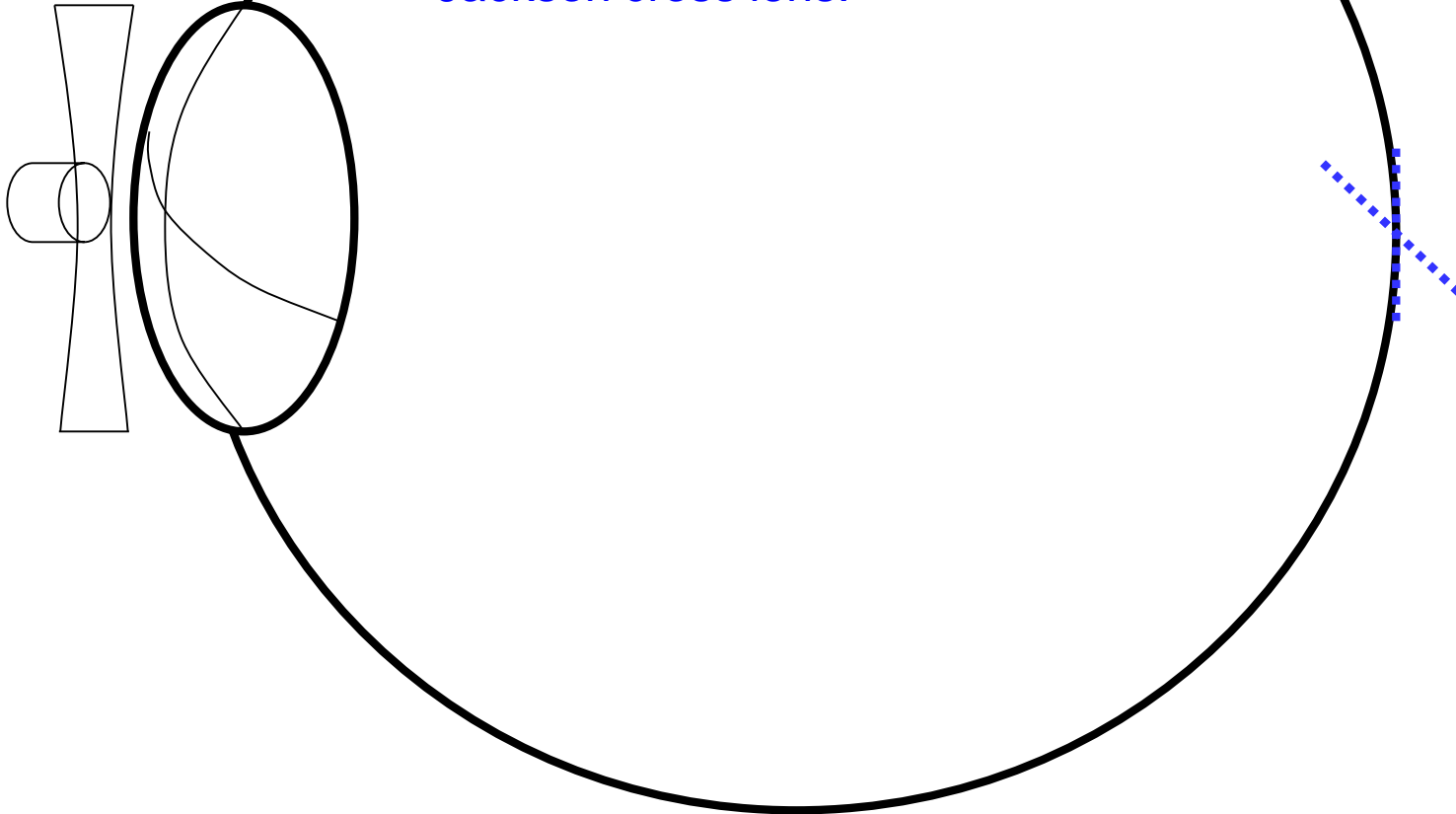
Astigmatic Correction: *Jackson Cross*



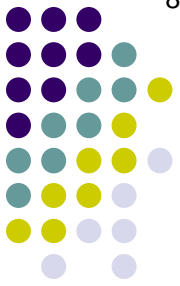
Eye Error:
+1 x 180
+5 x 090

+4x180
-5 Sph

The refractive error has been eliminated. However, we don't know this yet, and thus we reintroduce the Jackson cross lens.



Astigmatic Correction: *Jackson Cross*



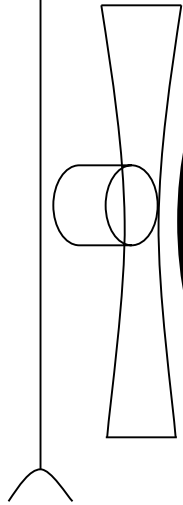
Eye Error:
+1 x 180
+5 x 090

The refractive error has been eliminated. However, we don't know this yet, and thus we reintroduce the Jackson cross lens.

In this orientation, the Jackson cross pulls the vertical focal line forward by 1D and pushes the horizontal focal line back 1D.

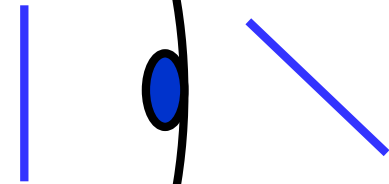
Conoid of Sturm
1D | 1D

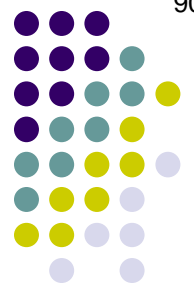
+4x180
-5 Sph



+1x090
-1x180

↑
Jackson Cross





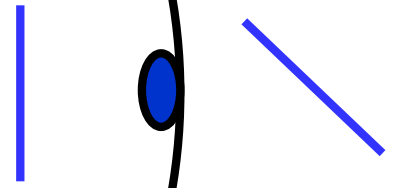
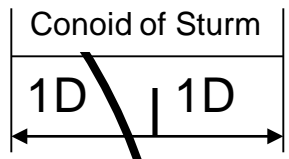
Astigmatic Correction: Jackson Cross

Eye Error:
+1 x 180
+5 x 090

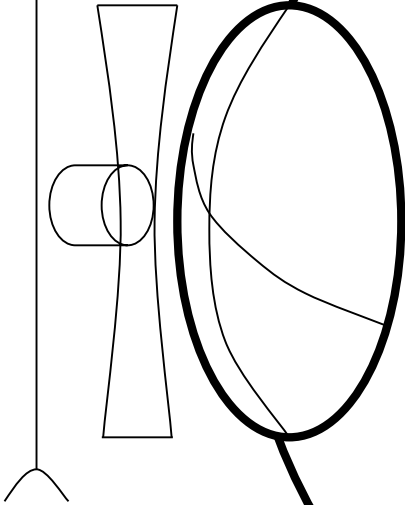
The refractive error has been eliminated. However, we don't know this yet, and thus we reintroduce the Jackson cross lens.

In this orientation, the Jackson cross pulls the vertical focal line forward by 1D and pushes the horizontal focal line back 1D.

Flip the Jackson cross.

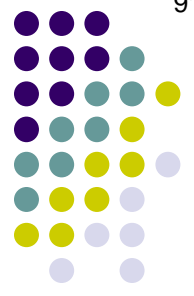


+4x180
-5 Sph



+1x090
-1x180

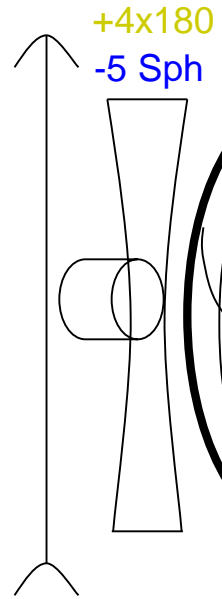
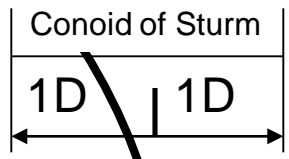
↑
Jackson
Cross



Astigmatic Correction: Jackson Cross

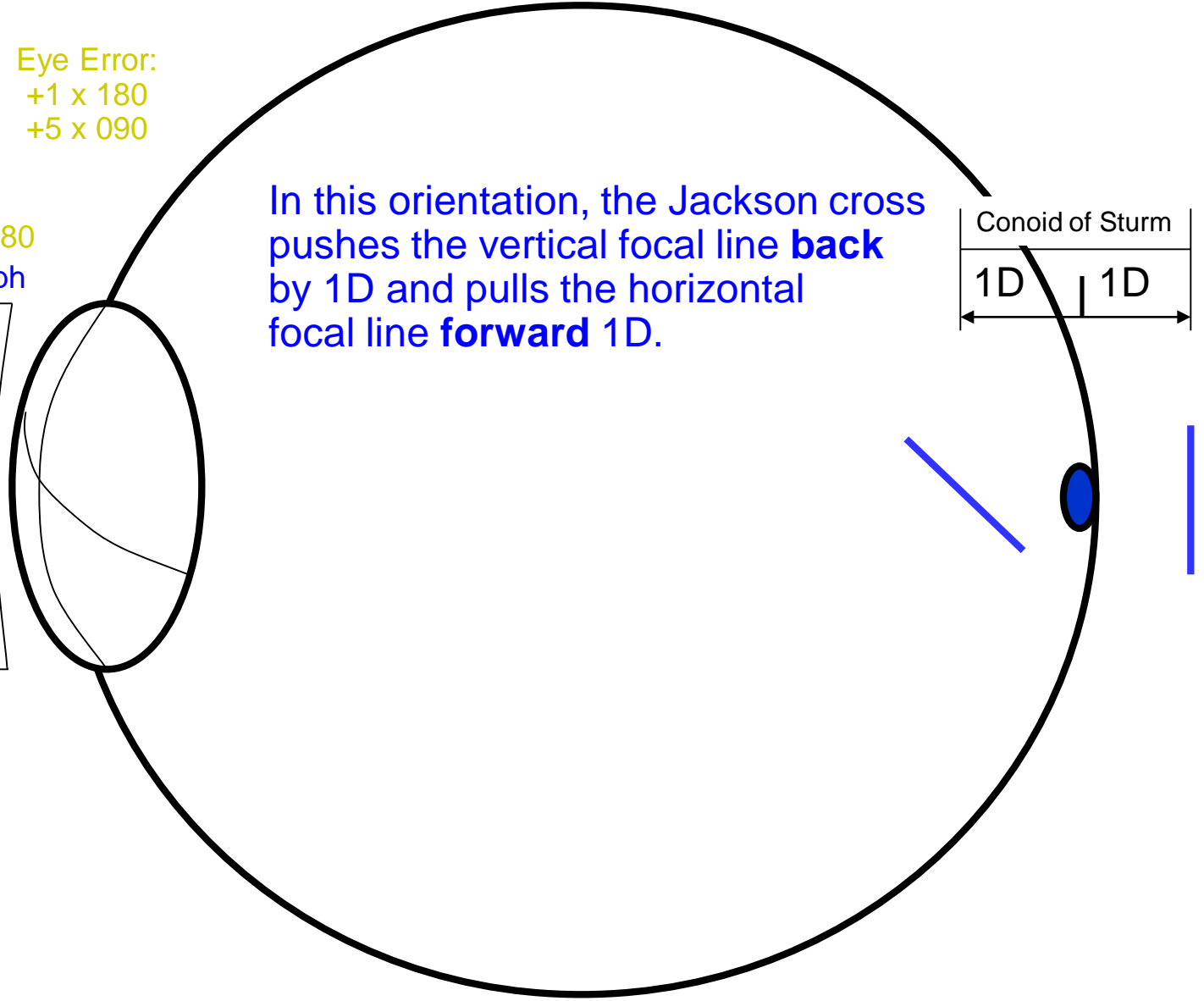
Eye Error:
+1 x 180
+5 x 090

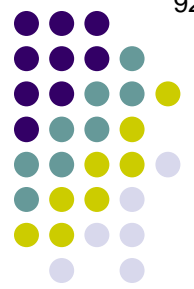
In this orientation, the Jackson cross pushes the vertical focal line **back** by 1D and pulls the horizontal focal line **forward** 1D.



-1x090
+1x180

↑
Jackson
Cross

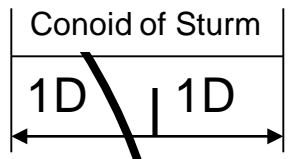




Astigmatic Correction: Jackson Cross

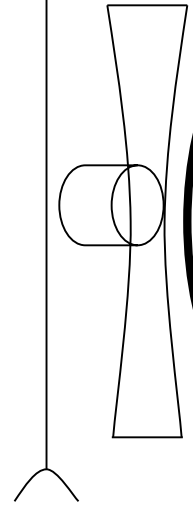
Eye Error:
+1 x 180
+5 x 090

In this orientation, the Jackson cross pushes the vertical focal line **back** by 1D and pulls the horizontal focal line **forward** 1D.



Flipping the Jackson cross between these two positions does not change the size of the Circle of Least Confusion; therefore, the patient perceives the images as **equally blurry**.

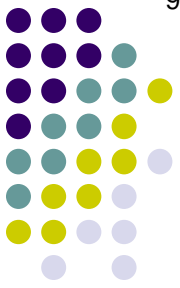
+4x180
-5 Sph



-1x090
+1x180

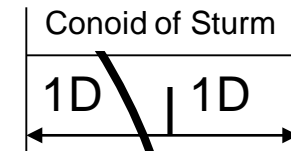
↑
Jackson Cross

Astigmatic Correction: *Jackson Cross*



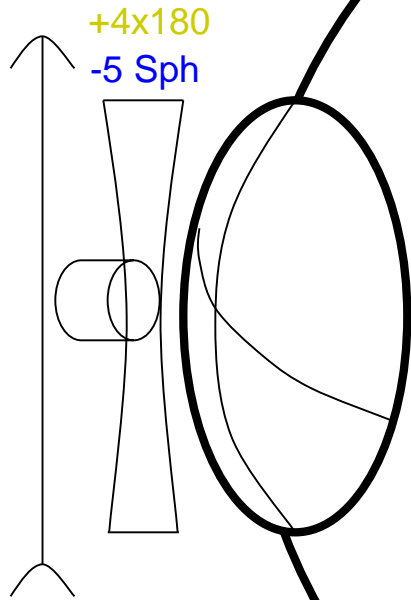
Eye Error:
 $+1 \times 180$
 $+5 \times 090$

In this orientation, the Jackson cross pushes the vertical focal line **back** by 1D and pulls the horizontal focal line **forward** 1D.



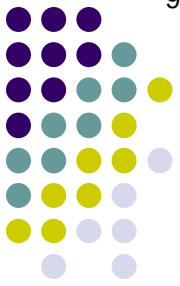
Flipping the Jackson cross between these two positions does not change the size of the Circle of Least Confusion; therefore, the patient perceives the images as **equally blurry**.

Because the images are **equally blurry**, we know the refractive error has been eliminated!



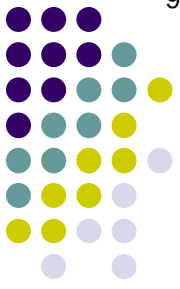
↑
Jackson Cross

Astigmatic Correction: *Jackson Cross*



Take a deep breath...

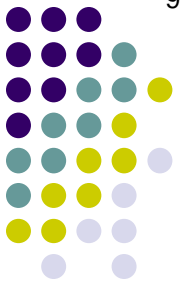
Astigmatic Correction: *Jackson Cross*



Take a deep breath...

Now we're ready to discuss the more difficult concepts involved in using the Jackson cross to determine cylinder ***axis***.

Astigmatic Correction: *Jackson Cross*

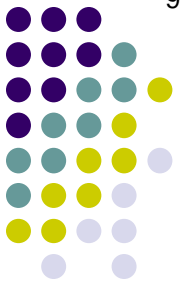


Take a deep breath...

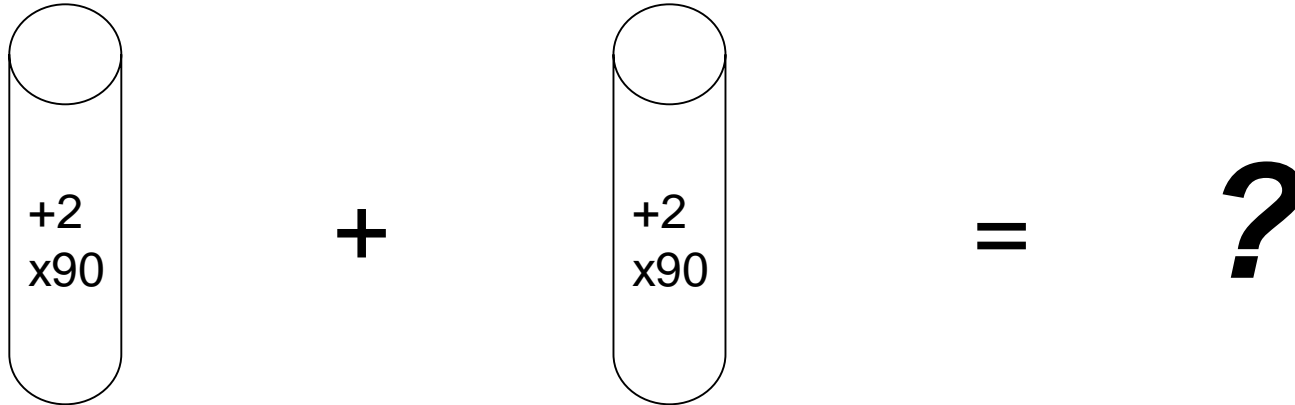
Now we're ready to discuss the more difficult concepts involved in using the Jackson cross to determine cylinder ***axis***.

But first, let's talk more about combining cylinders...

Astigmatic Correction: *Jackson Cross*

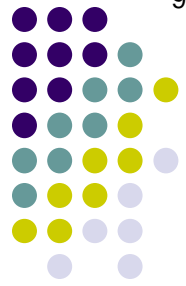


Combining PLUS Cylinders

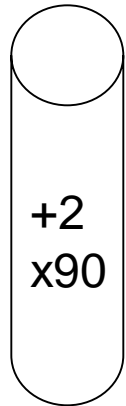


What will be the resulting lens when two identical plus cylinders of identical orientation are combined?

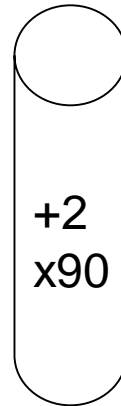
Astigmatic Correction: *Jackson Cross*



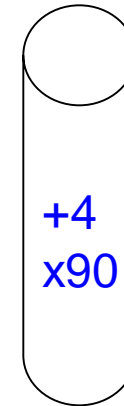
Combining PLUS Cylinders



+



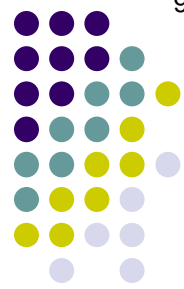
=



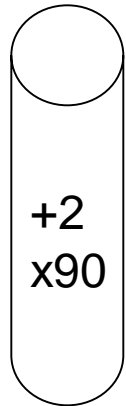
*No sphere
All cylinder*

What will be the resulting lens when two identical plus cylinders of identical orientation are combined?
A cylindrical lens with axis identical to that of the parent cylinders and power equal to the **sum** of their powers.
Note that the resultant lens has **no** spherical power.

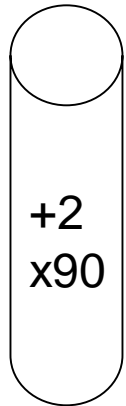
Astigmatic Correction: *Jackson Cross*



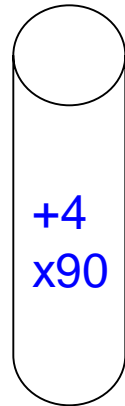
Combining PLUS Cylinders



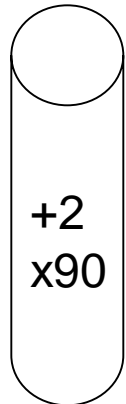
+



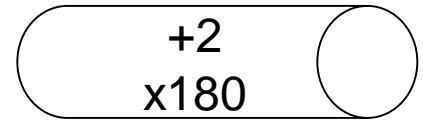
=



*No sphere
All cylinder*



+



=

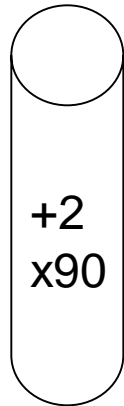
?

What will be the resulting lens when two identical plus cylinders oriented 90° apart are combined?

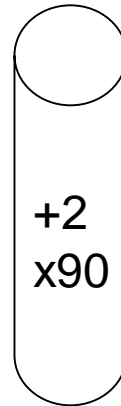
Astigmatic Correction: *Jackson Cross*



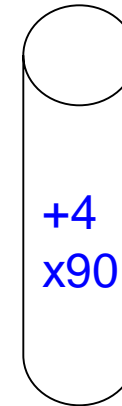
Combining PLUS Cylinders



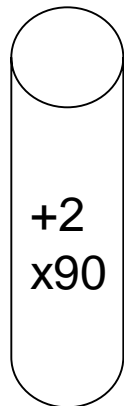
+



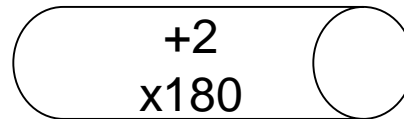
=



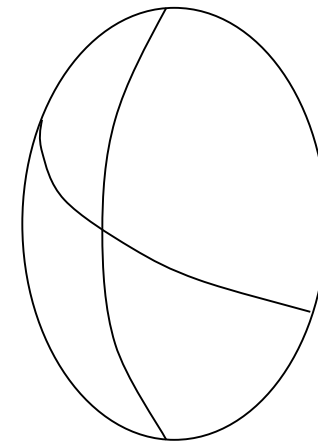
*No sphere
All cylinder*



+



=



*All sphere
No cylinder*

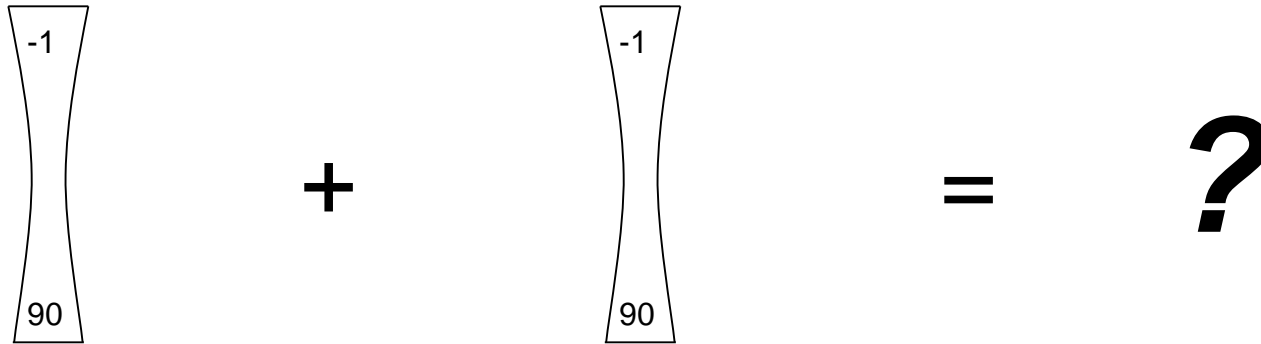
+2 sphere

What will be the resulting lens when two identical plus cylinders oriented **90° apart** are combined?
A spherical lens with **no** cylinder; its power is the same as (**not** the sum of) that of the parent lenses.

Astigmatic Correction: *Jackson Cross*



Combining MINUS Cylinders

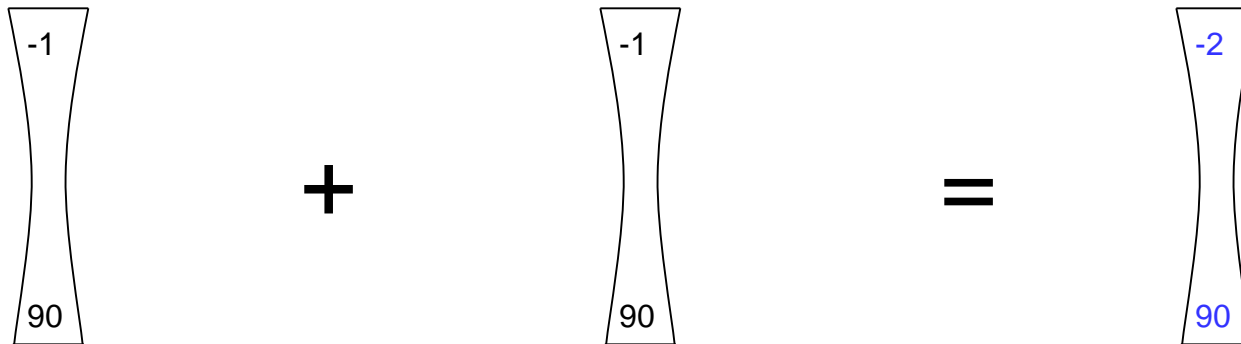


What will be the resulting lens when two identical **minus** cylinders of identical orientation are combined?

Astigmatic Correction: *Jackson Cross*



Combining MINUS Cylinders



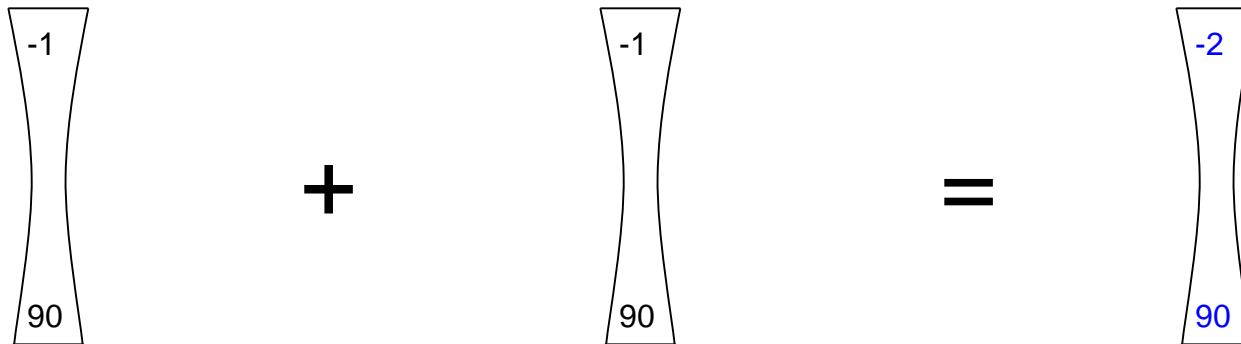
*No sphere
All cylinder*

*What will be the resulting lens when two identical **minus** cylinders of identical orientation are combined?
The same as in the plus-cylinder situation: A cylindrical lens with axis identical to that of the parent cylinders, power equal to the sum of their powers, and no spherical power.*

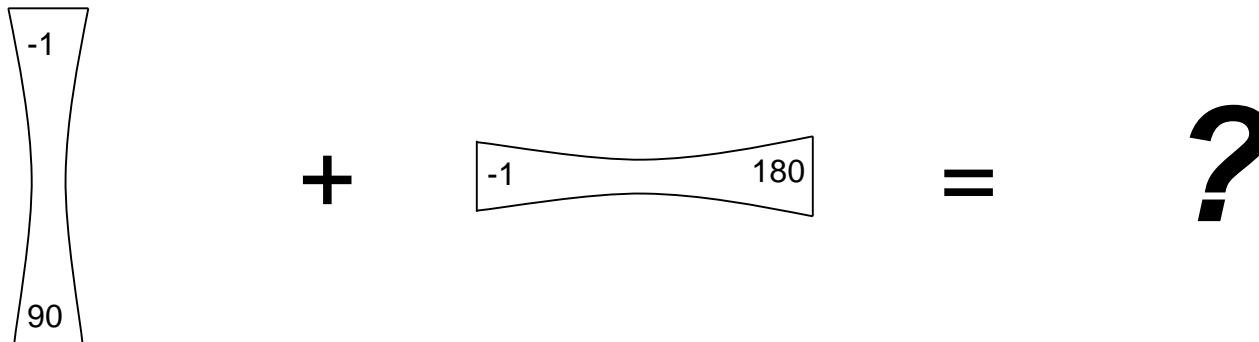
Astigmatic Correction: *Jackson Cross*



Combining MINUS Cylinders

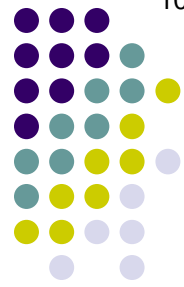


*No sphere
All cylinder*

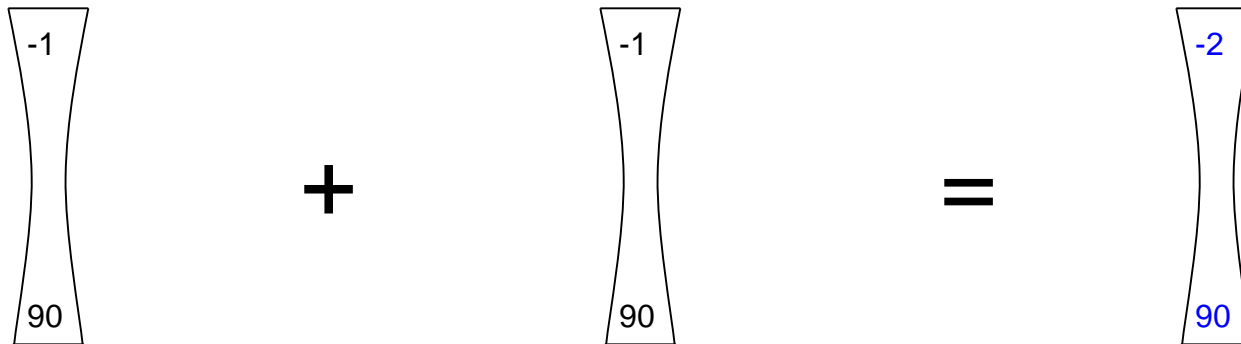


What will be the resulting lens when two identical minus cylinders oriented 90° apart are combined?

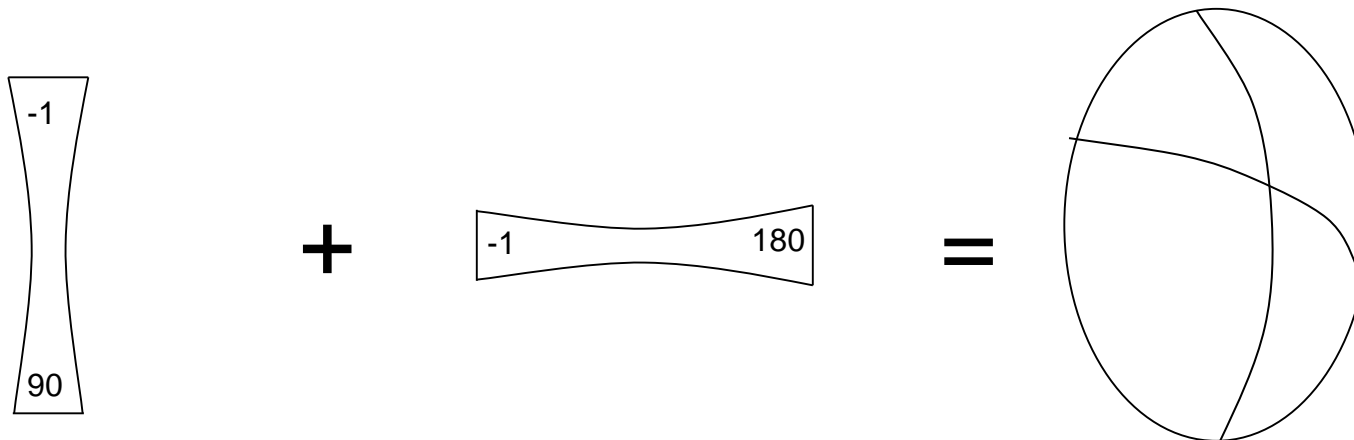
Astigmatic Correction: *Jackson Cross*



Combining MINUS Cylinders



*No sphere
All cylinder*



*All sphere
No cylinder*

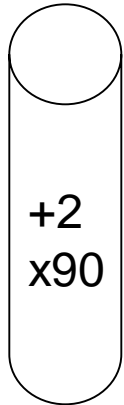
-1 sphere

*What will be the resulting lens when two identical minus cylinders oriented **90° apart** are combined?
Same as with the plus: A spherical lens with no cylinder, and power the same as that of the parent lenses.*

Astigmatic Correction: *Jackson Cross*



Combining **MIXED** Cylinders



+



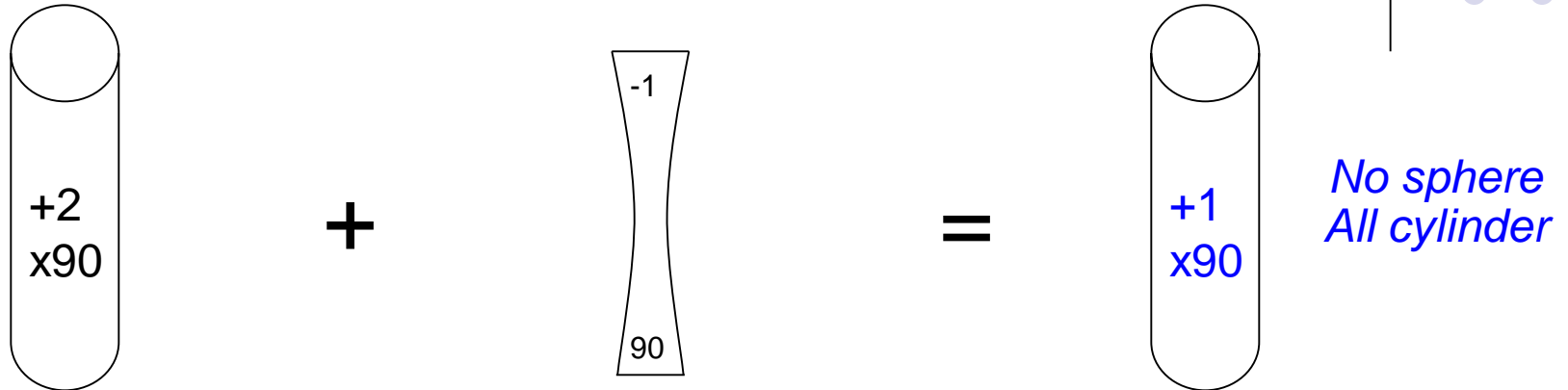
=

?

But what if the lens is of mixed parentage, with a plus and a minus lens of identical axis but different powers?

Astigmatic Correction: *Jackson Cross*

Combining **MIXED** Cylinders

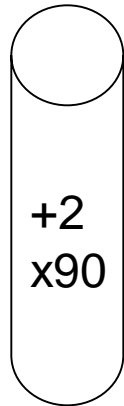


But what if the lens is of mixed parentage, with a plus and a minus lens of identical axis but different powers? As with the 'purebred' cases, the resultant will be a cylindrical lens with axis identical to that of the parent cylinders and power equal to the sum of their powers, with no spherical power.

Astigmatic Correction: *Jackson Cross*



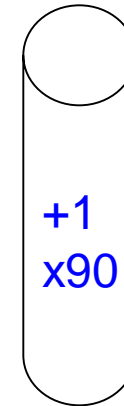
Combining **MIXED** Cylinders



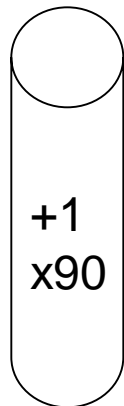
+



=



*No sphere
All cylinder*



+



=

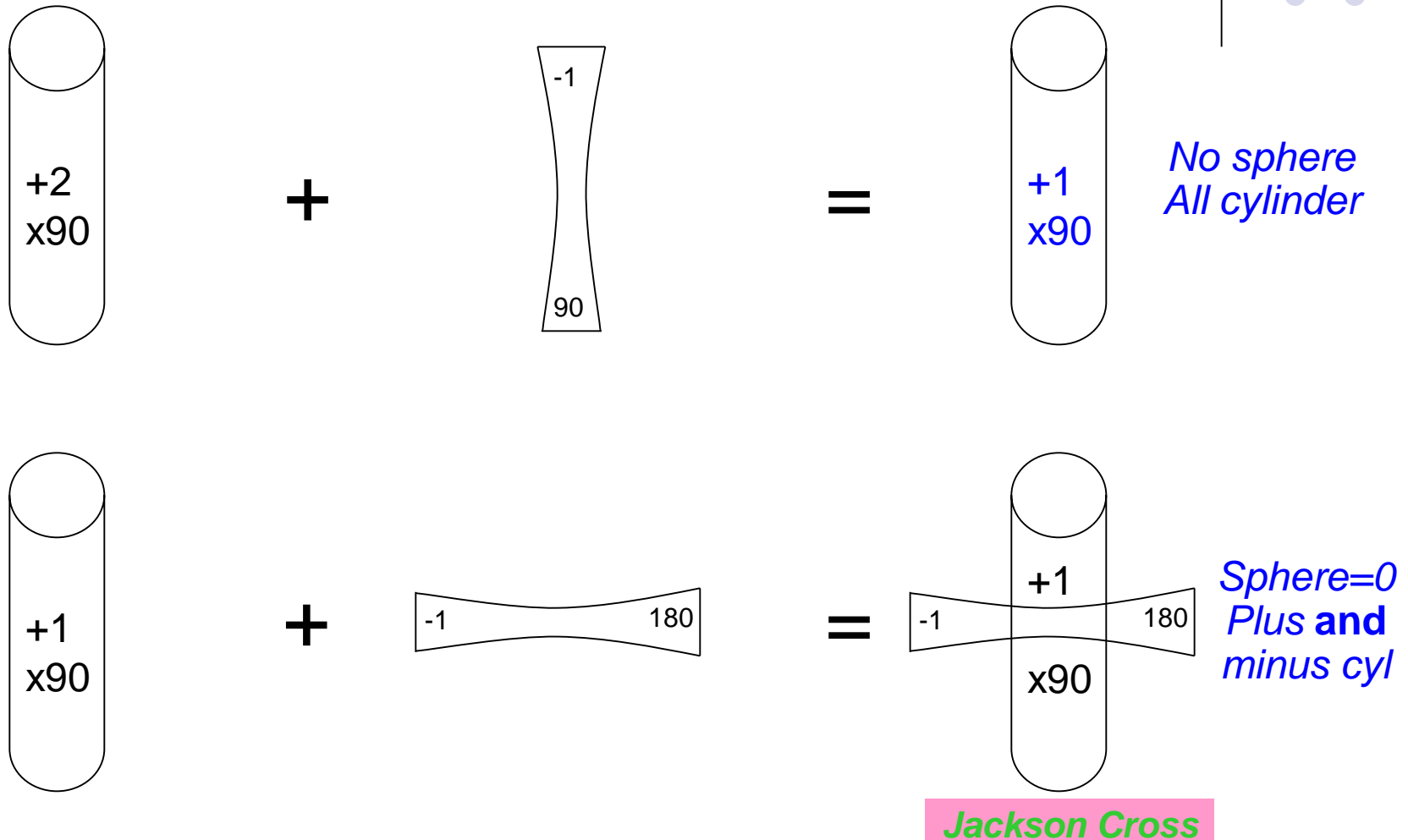
?

What if the plus and minus parents are of identical powers but oriented 90° apart?

Astigmatic Correction: *Jackson Cross*

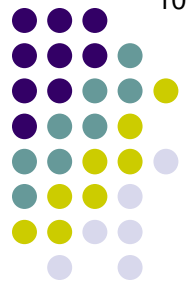


Combining **MIXED** Cylinders



What if the plus and minus parents are of identical powers but oriented 90° apart?
 This is the definition of a **Jackson cross** lens. (You recognized that immediately, though.)

Astigmatic Correction: *Jackson Cross*

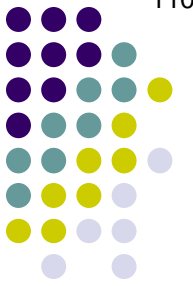


BUT, in each of these situations, the orientation of the cylinder combination has been *regular*: either **on-axis** or **90° apart**.

But what if the alignment is *oblique*, i.e., neither on-axis nor 90° apart?

Astigmatic Correction: *Jackson Cross*

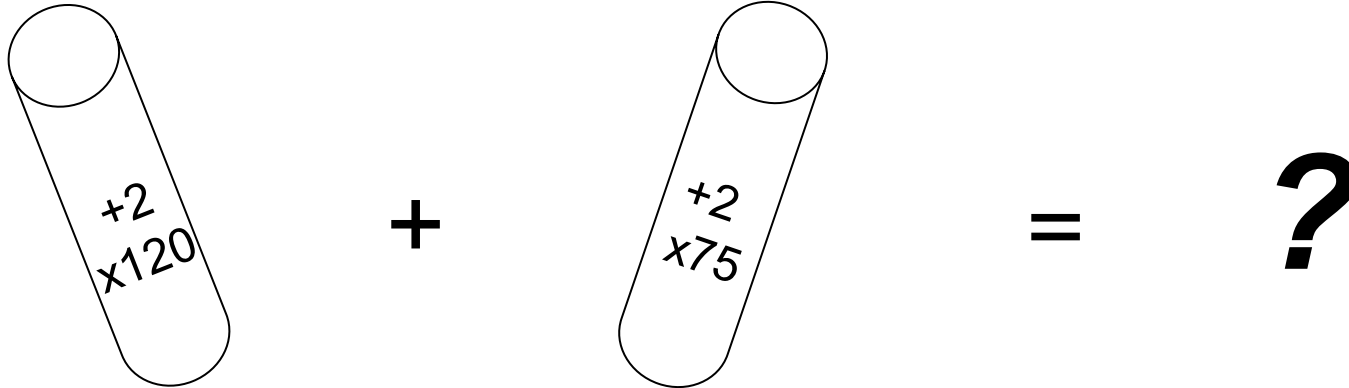
Combining Oblique Cylinders: SAME Sign



Astigmatic Correction: *Jackson Cross*



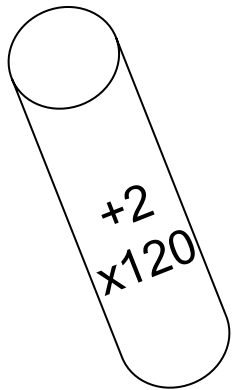
Combining Oblique Cylinders: SAME Sign



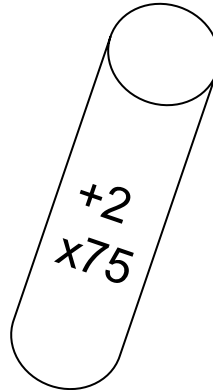
What will be the resulting lens when two identical plus cylinders with oblique orientation are combined?

Astigmatic Correction: *Jackson Cross*

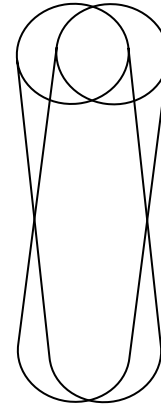
Combining Oblique Cylinders: SAME Sign



+

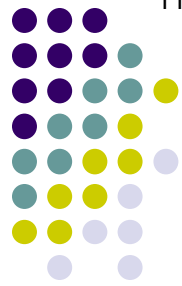


=



Some sphere
Some cylinder
Axis between

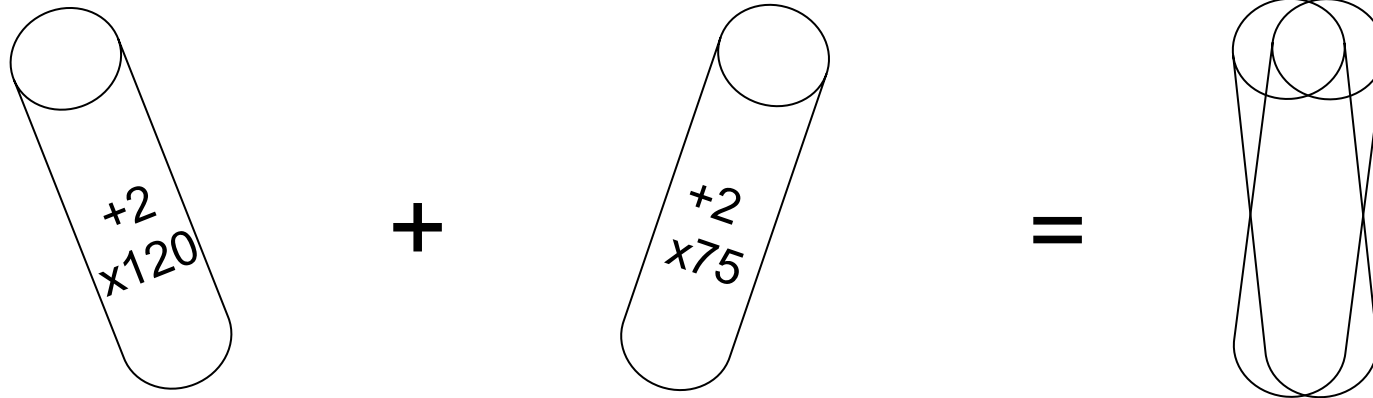
What will be the resulting lens when two identical plus cylinders with oblique orientation are combined?
A **spherocylindrical** lens with the axis of plus power oriented between the axes of the parent cylinders.
(An equivalent result would occur if two identical **minus** cylinders were similarly combined.)



Astigmatic Correction: *Jackson Cross*

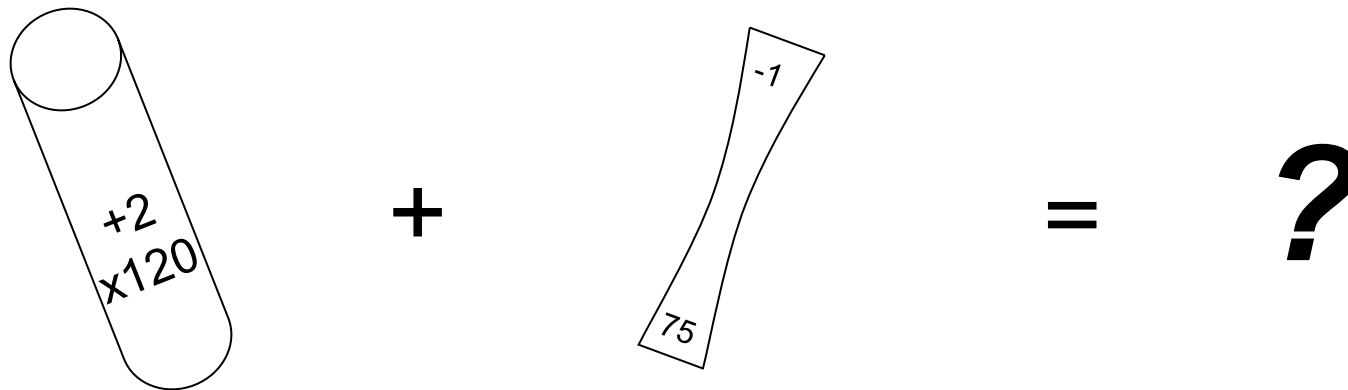


Combining Oblique Cylinders: SAME Sign



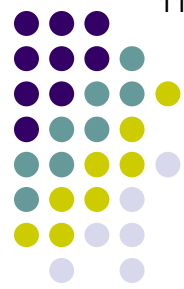
Some sphere
Some cylinder
Axis between

Combining Oblique Cylinders: DIFFERENT Sign

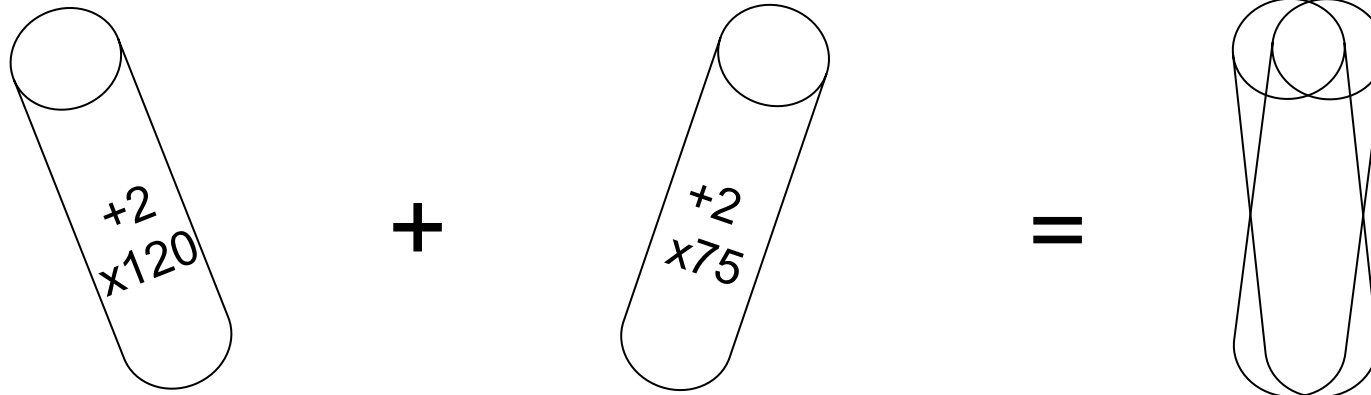


What if the obliquely-oriented parent cylinders are of **different signs**?

Astigmatic Correction: *Jackson Cross*

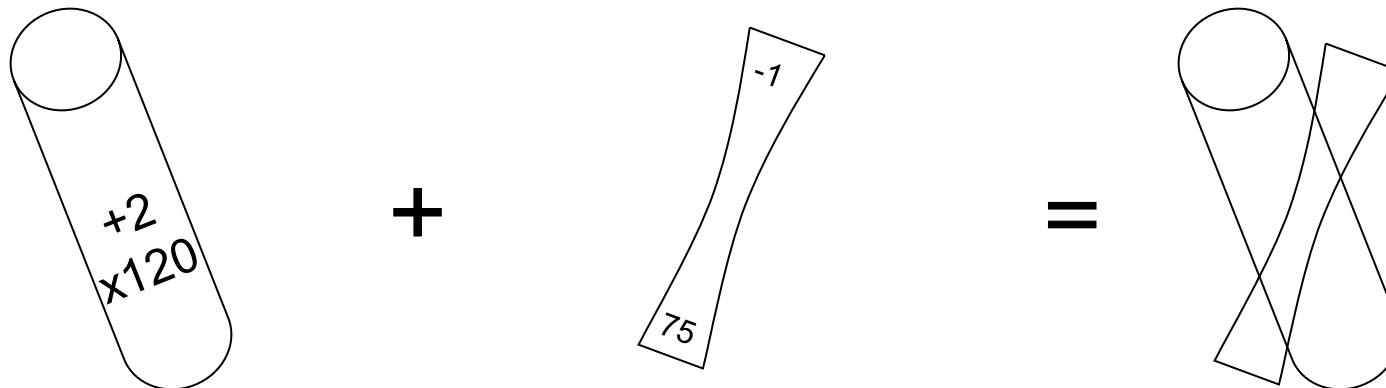


Combining Oblique Cylinders: SAME Sign



Some sphere
Some cylinder
Axis between

Combining Oblique Cylinders: DIFFERENT Sign

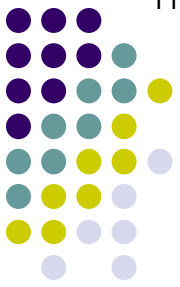


Some sphere
Some cylinder
~~Axis between~~

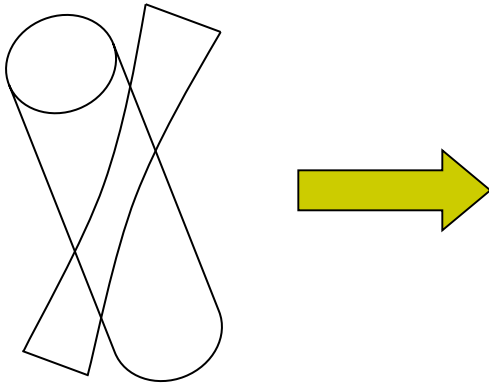
What if the obliquely-oriented parent cylinders are of **different signs**?

As in the same-sign situation, a spherocylindrical lens will result. However, the axis of cylinder power will **not** be oriented between the axes of the parent cylinders! Let's look at this in more detail...

Astigmatic Correction: *Jackson Cross*

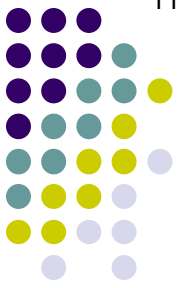


Combining Oblique Cylinders:
DIFFERENT Sign

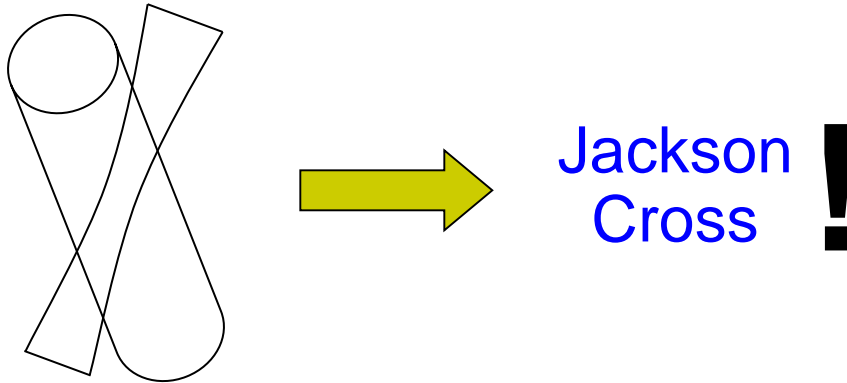


When cylinders of opposite sign and oblique orientation are combined, the resultant lens is...

Astigmatic Correction: *Jackson Cross*

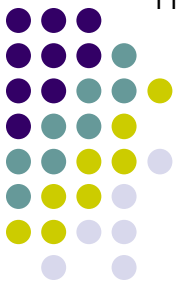


Combining Oblique Cylinders:
DIFFERENT Sign

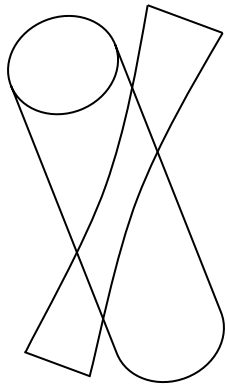


When cylinders of opposite sign and oblique orientation are combined, the resultant lens is...a *Jackson cross*!

Astigmatic Correction: *Jackson Cross*



Combining Oblique Cylinders:
DIFFERENT Sign

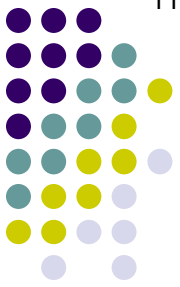


Jackson
Cross !

Power?
Axes?

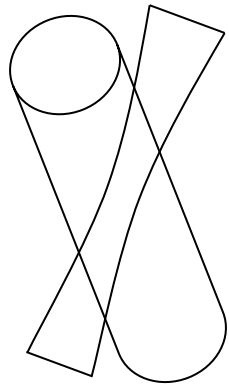
When cylinders of opposite sign and oblique orientation are combined, the resultant lens is...a *Jackson cross*!
Understanding the specific orientation of the axes of the resultant Jackson cross requires a new concept...

Astigmatic Correction: *Jackson Cross*

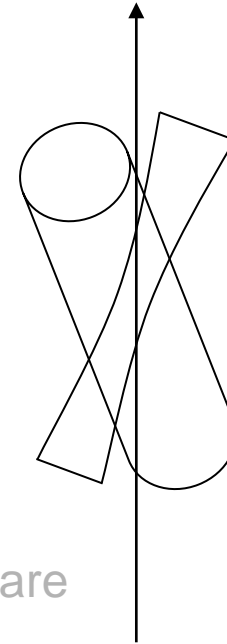


Combining Oblique Cylinders:
DIFFERENT Sign

'Bisector Angle'
 $\frac{1}{2}$ between cylinder axes
(if powers are equal)



Jackson
Cross



When cylinders of opposite sign and oblique orientation are combined, the resultant lens is...a *Jackson cross*!

Understanding the specific orientation of the axes of the resultant Jackson cross requires a new concept...

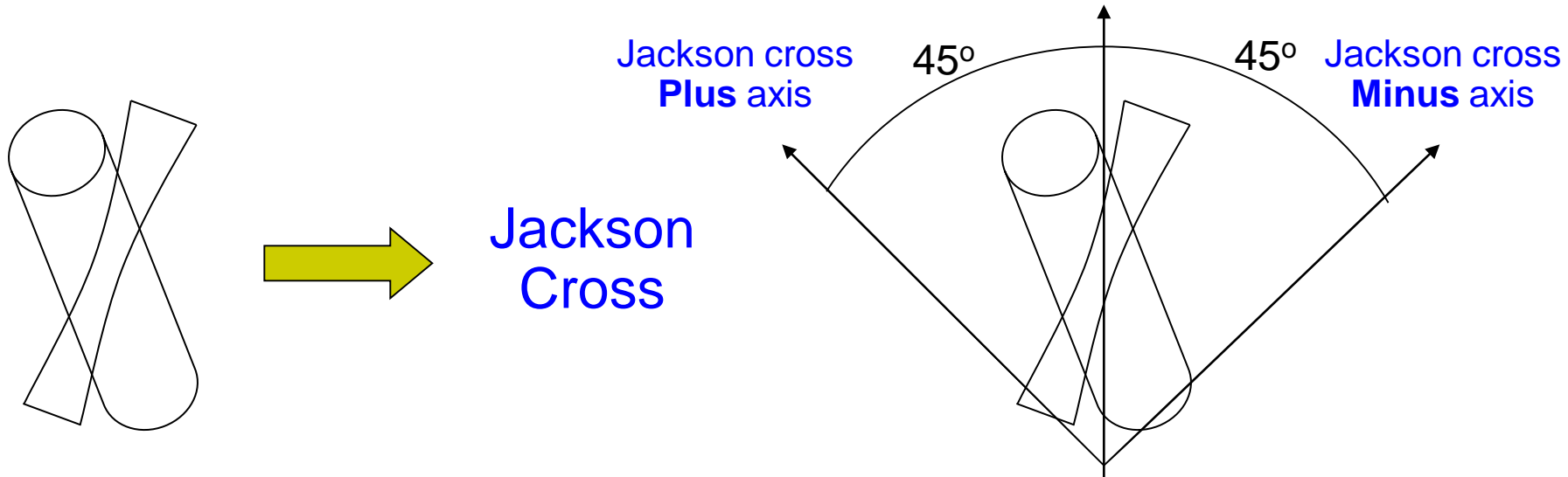
The **bisector angle**: The axis halfway between those of the parent cylinders (assuming they are of equal but opposite powers).

Astigmatic Correction: *Jackson Cross*



Combining Oblique Cylinders:
DIFFERENT Sign

'Bisector Angle'
 $\frac{1}{2}$ between cylinder axes
(if powers are equal)



When cylinders of opposite sign and oblique orientation are combined, the resultant lens is...a *Jackson cross*!

Understanding the specific orientation of the axes of the resultant Jackson cross requires a new concept...

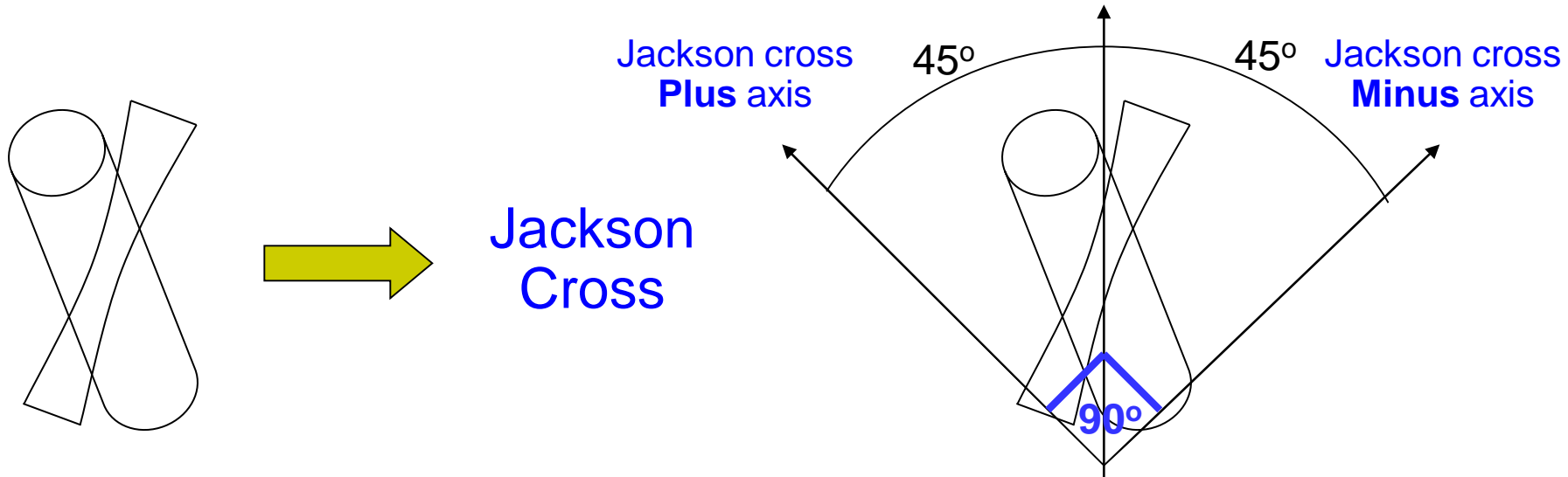
The ***bisector angle***: The axis halfway between those of the parent cylinders (assuming they are of equal but opposite powers). **The axes of the resultant Jackson cross are to be found 45° to each side of the bisector angle.**

Astigmatic Correction: *Jackson Cross*



Combining Oblique Cylinders:
DIFFERENT Sign

'Bisector Angle'
 $\frac{1}{2}$ between cylinder axes
(if powers are equal)



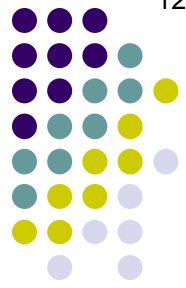
When cylinders of opposite sign and oblique orientation are combined, the resultant lens is...a *Jackson cross*!

Understanding the specific orientation of the axes of the resultant Jackson cross requires a new concept...

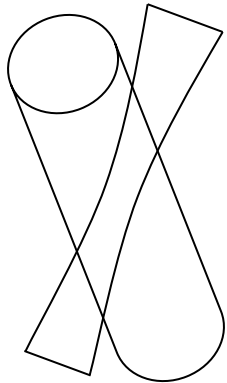
The ***bisector angle***: The axis halfway between those of the parent cylinders (assuming they are of equal but opposite powers). **The axes of the resultant Jackson cross are to be found 45° to each side of the bisector angle.**

(Note that this 'double 45° requirement' puts the axes 90° apart, as is required in a Jackson cross.)

Astigmatic Correction: *Jackson Cross*



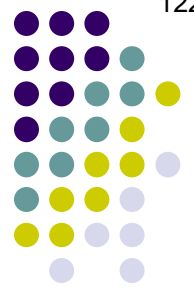
For Example...



-2 x 085 +2 x 095

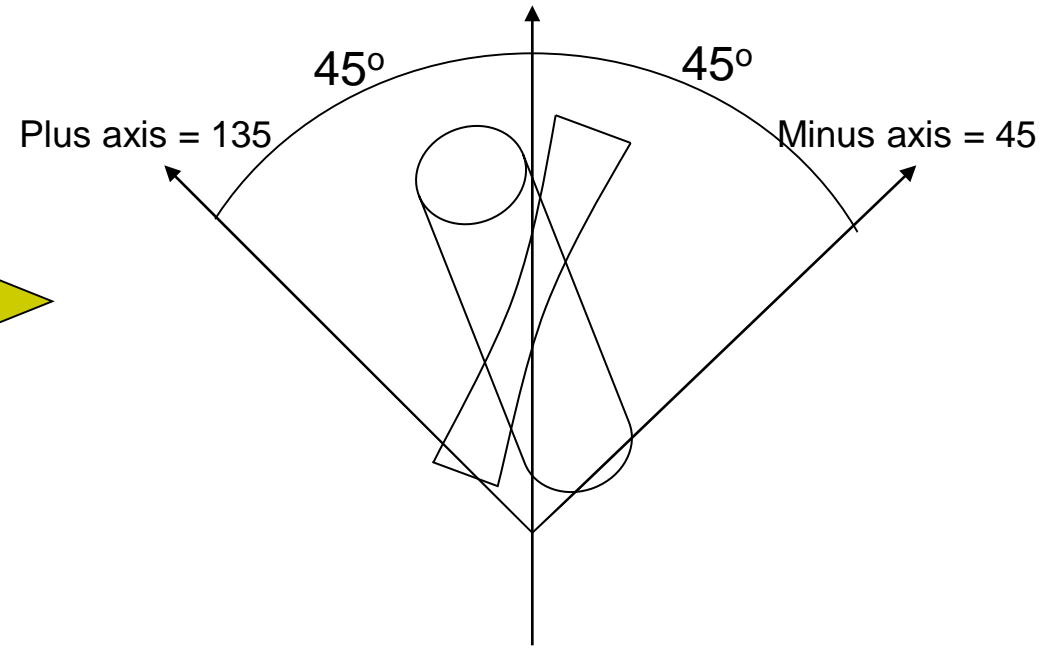
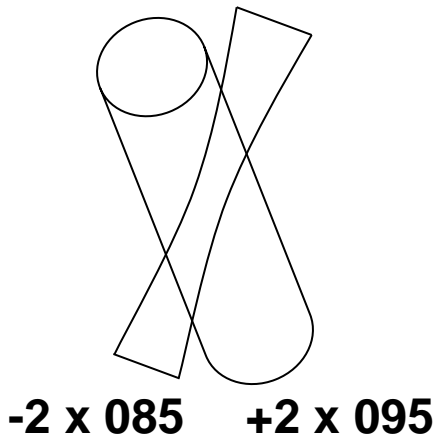


Astigmatic Correction: *Jackson Cross*

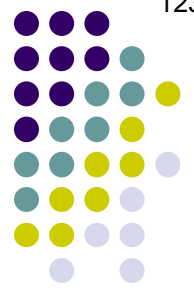


For Example...

Bisector Angle = 090

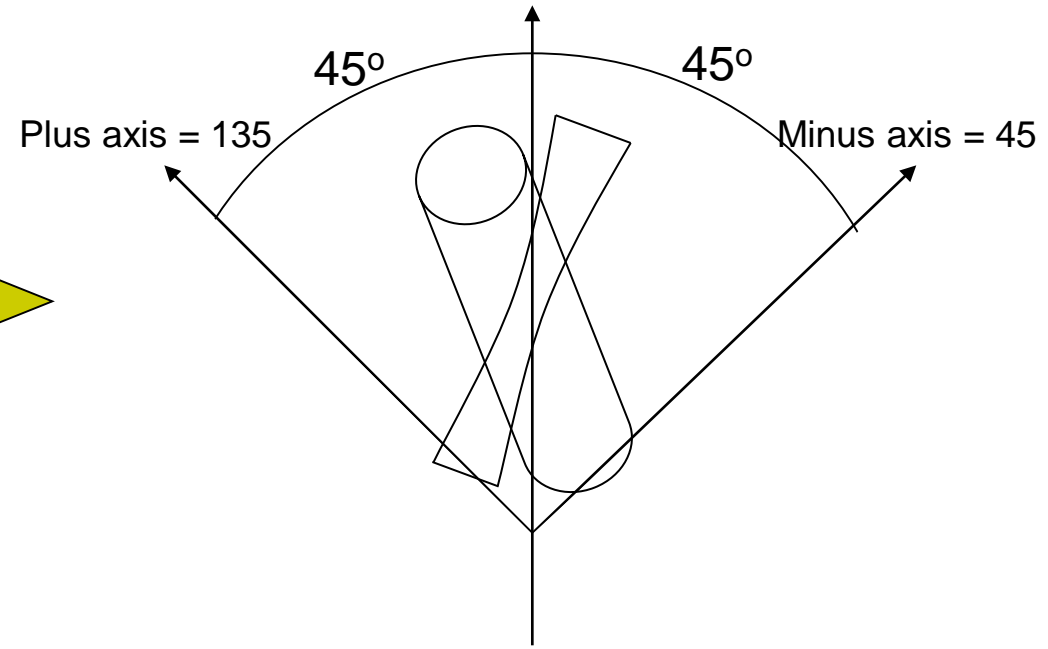
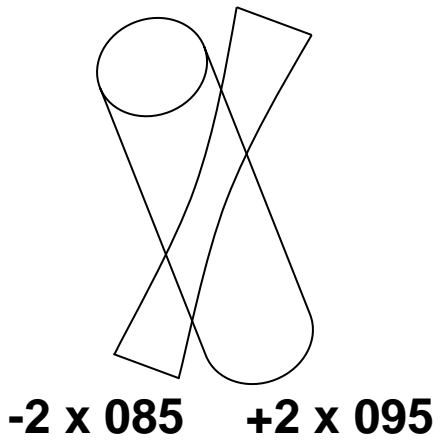


Astigmatic Correction: *Jackson Cross*



For Example...

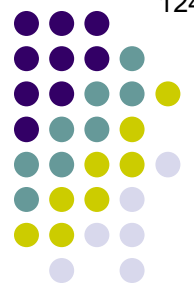
Bisector Angle = 090



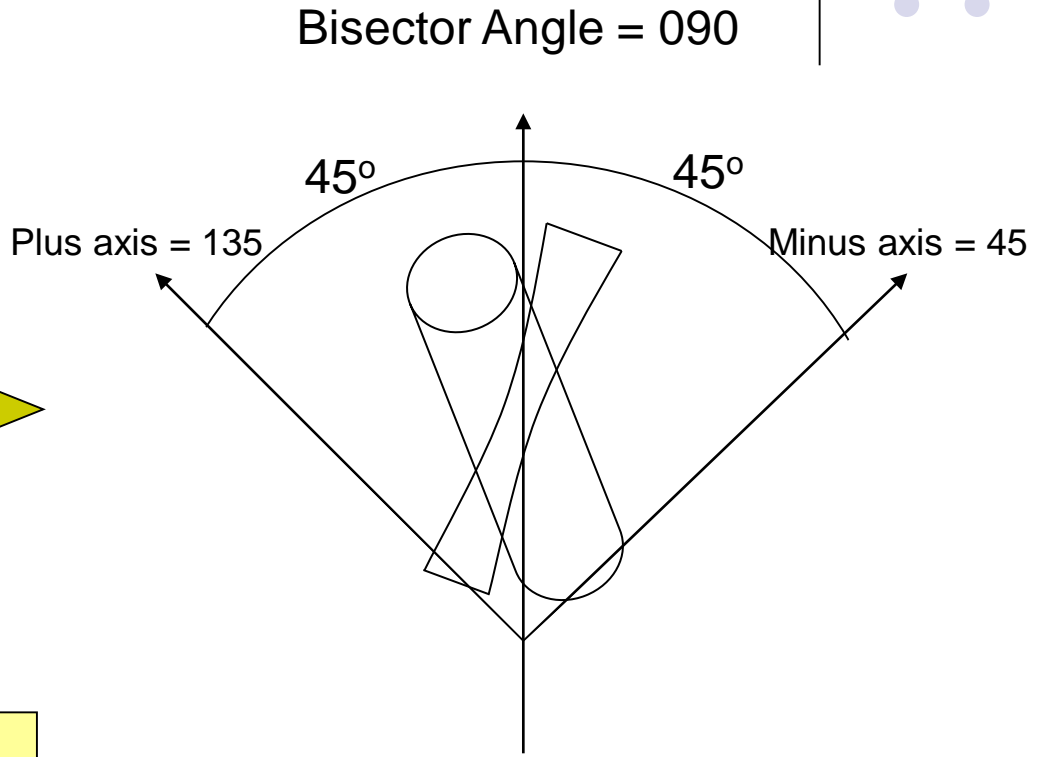
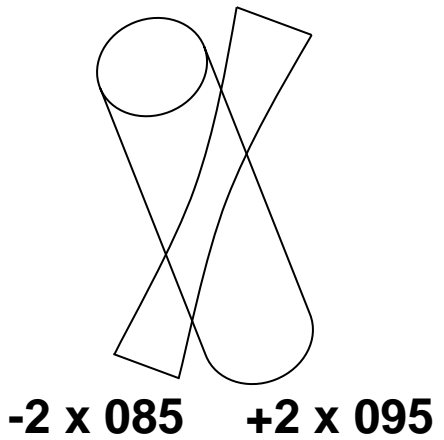
Resultant:
- .35 + .70 x 135

(Note that this is in fact a Jackson cross)

Astigmatic Correction: *Jackson Cross*



For Example...

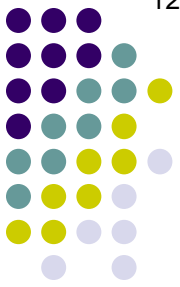


Why should we care about all of this cylinder mumbo-jumbo?

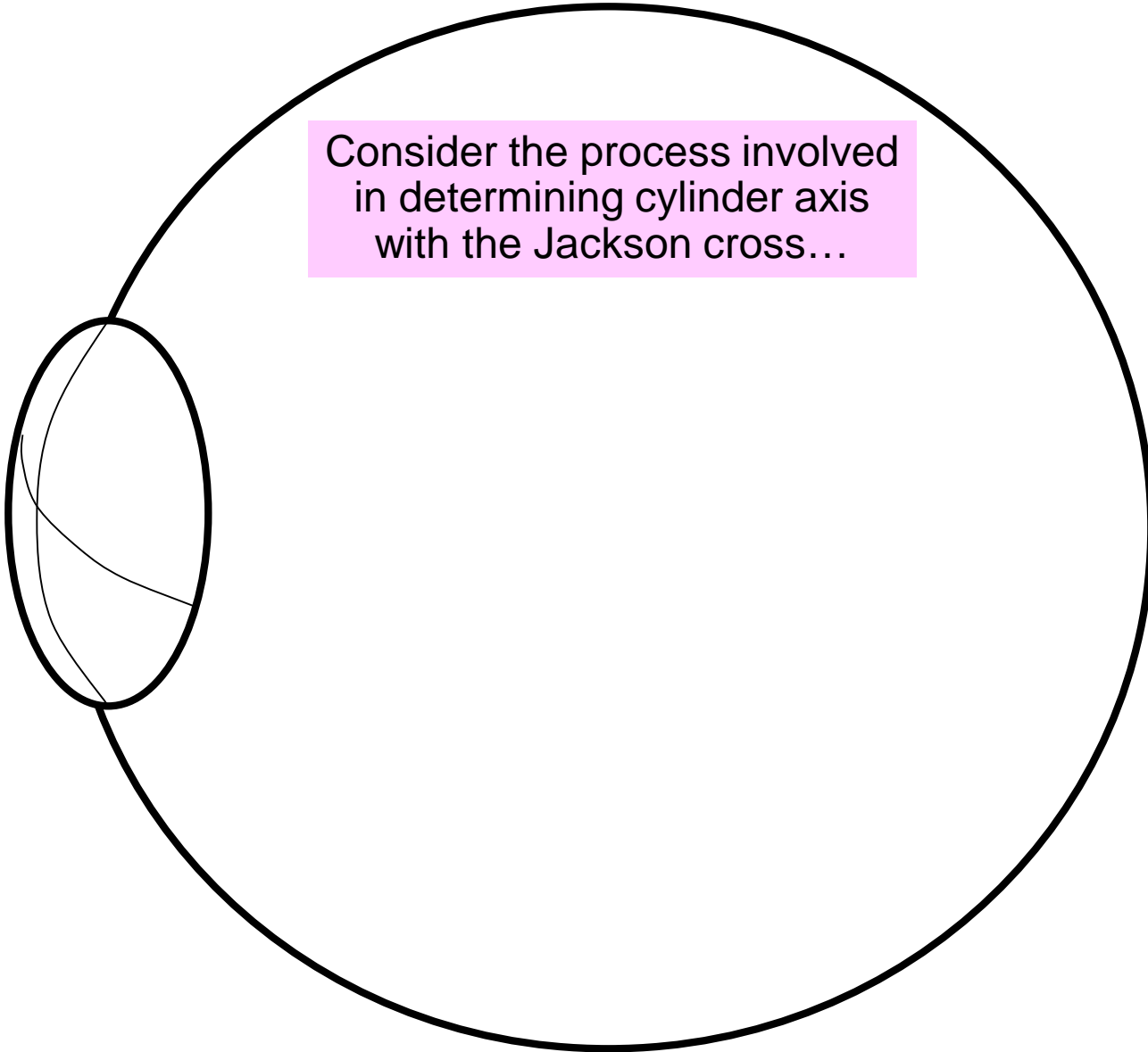
Resultant:
-0.35 +0.70 x 135

(Note that this is in fact a Jackson cross)

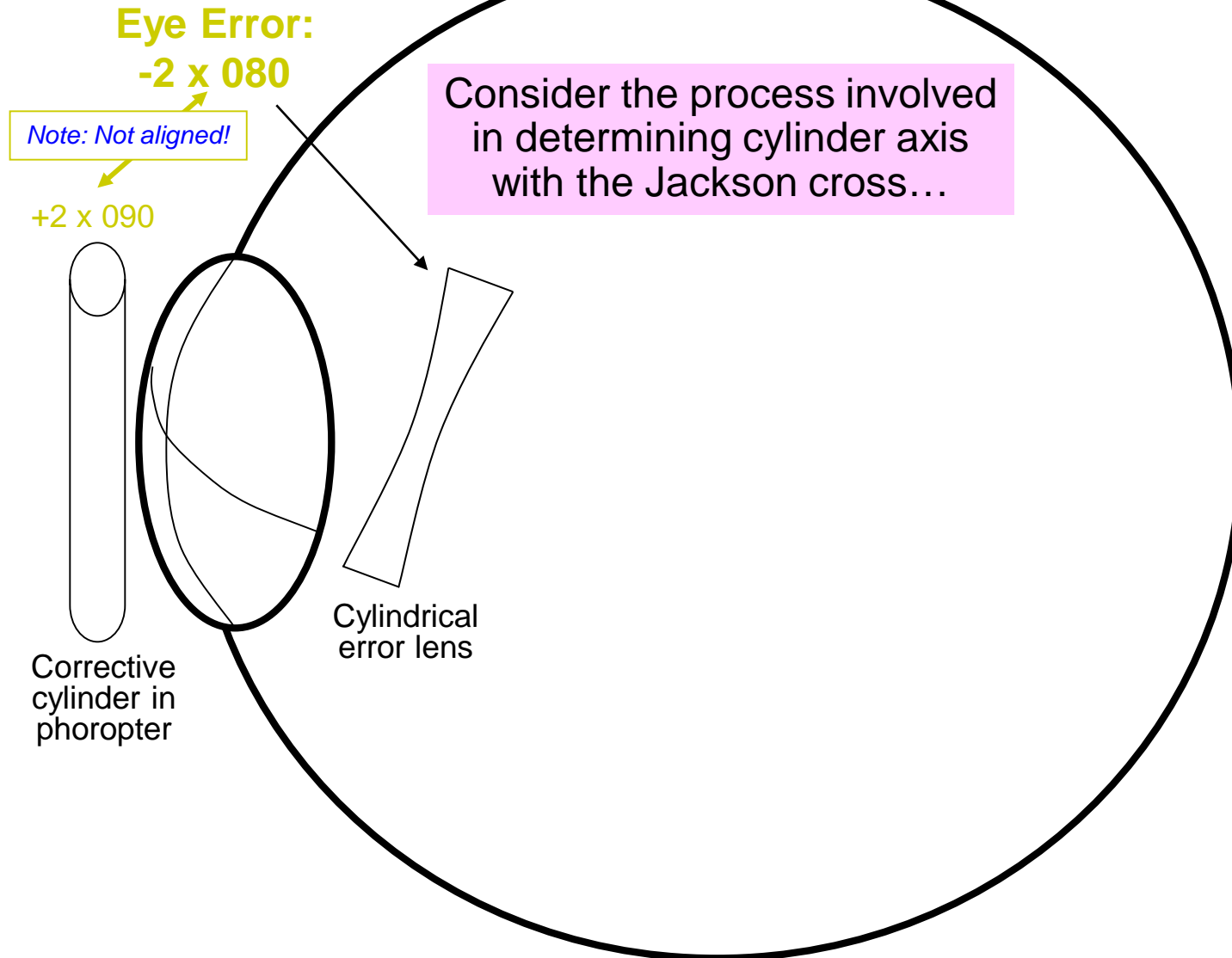
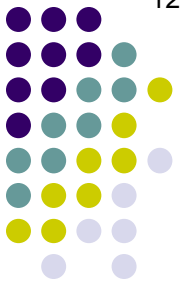
Astigmatic Correction: *Jackson Cross*



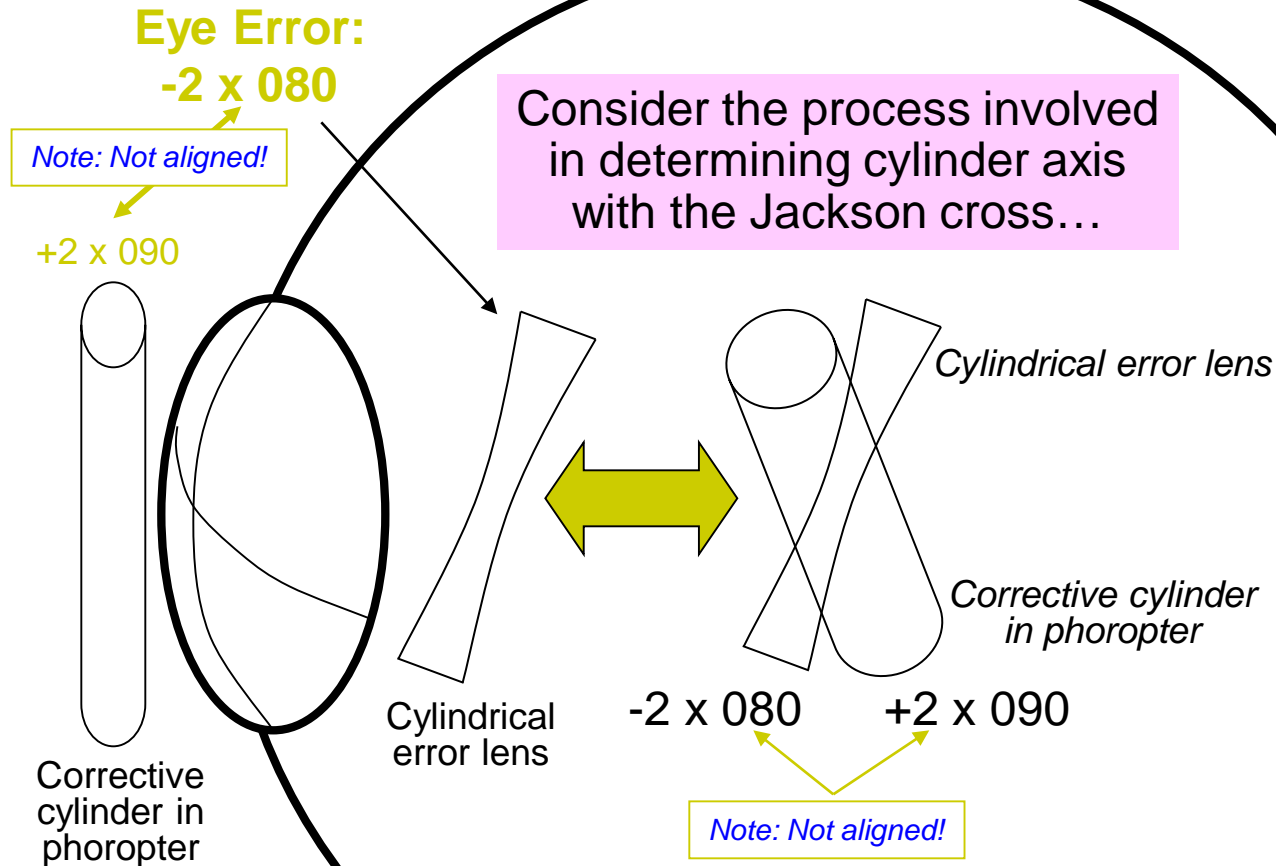
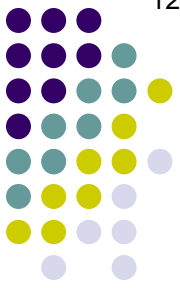
Consider the process involved
in determining cylinder axis
with the Jackson cross...



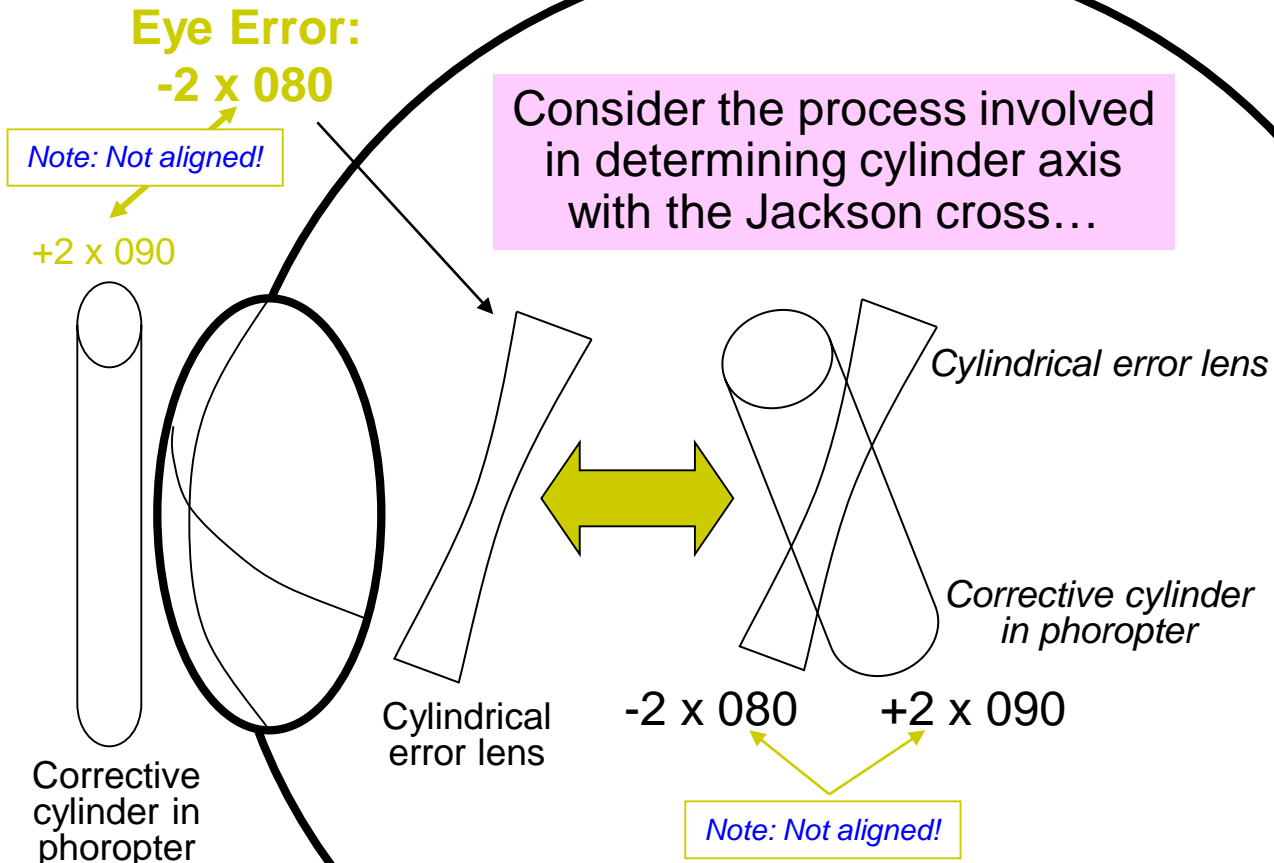
Astigmatic Correction: *Jackson Cross*



Astigmatic Correction: *Jackson Cross*

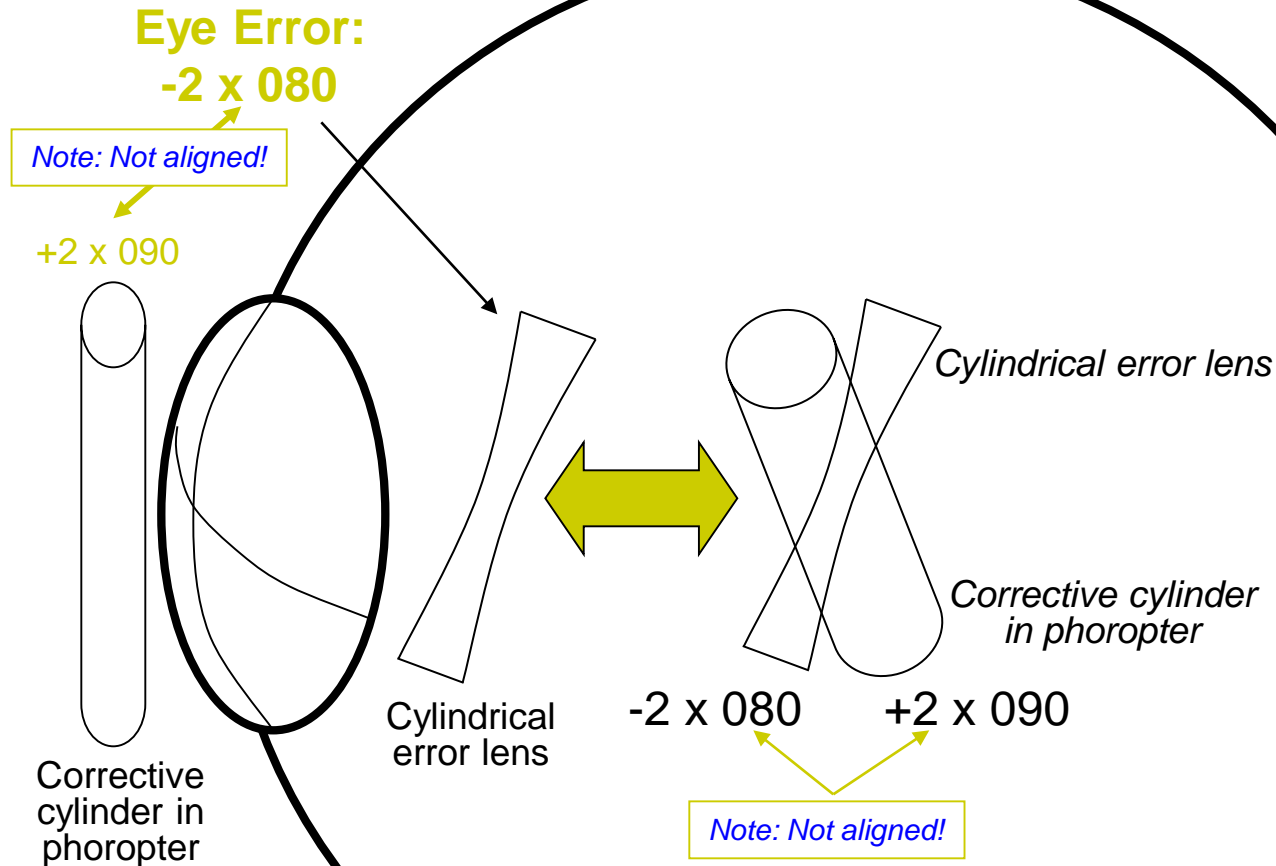


Astigmatic Correction: *Jackson Cross*



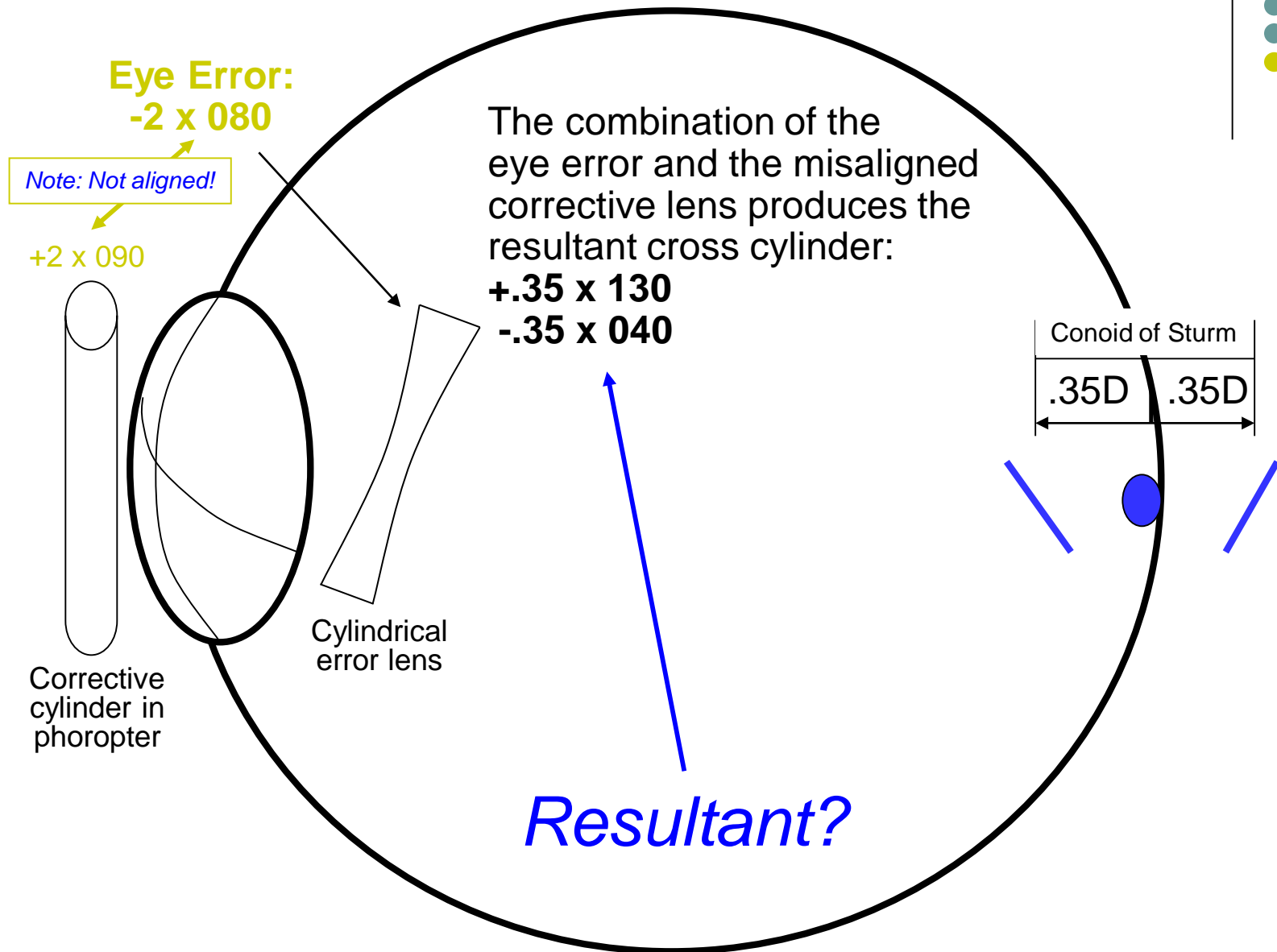
This is why we care—axis determination with the Jackson cross involves combining off-axis cylinders of opposite signs!

Astigmatic Correction: *Jackson Cross*

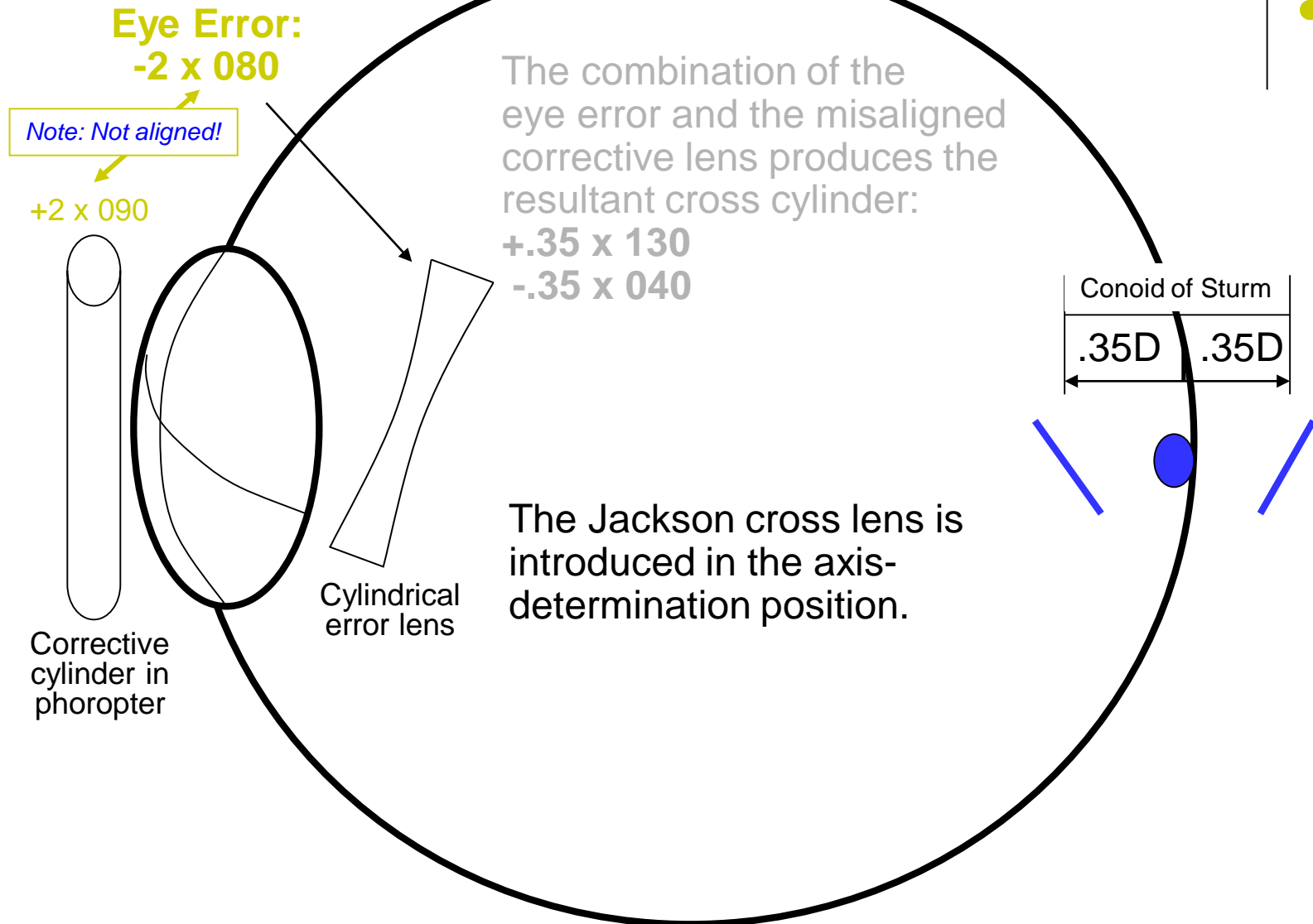


Resultant?

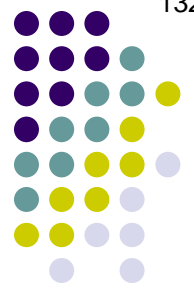
Astigmatic Correction: *Jackson Cross*



Astigmatic Correction: *Jackson Cross*



Astigmatic Correction: *Jackson Cross*

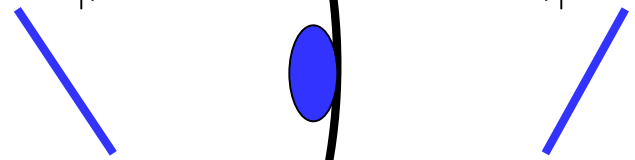
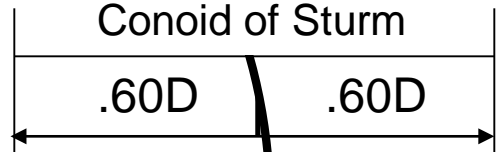
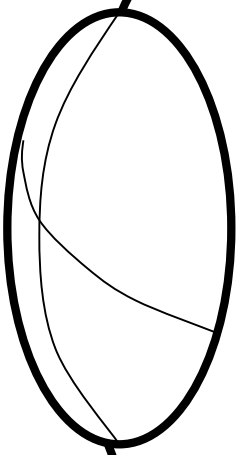
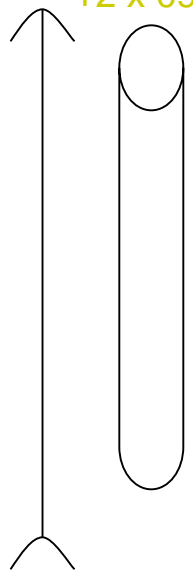


Eye Error:
-2 x 080

With this orientation of the cross, the focal lines become **longer**, which makes the Circle of Least Confusion **larger**.

Resultant:
+.35 x 130
-.35 x 040

+2 x 090



+.25 x 130
-.25 x 040

↑
Jackson Cross

Astigmatic Correction: *Jackson Cross*

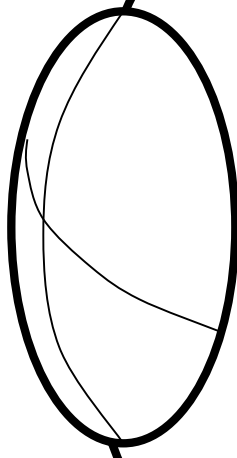
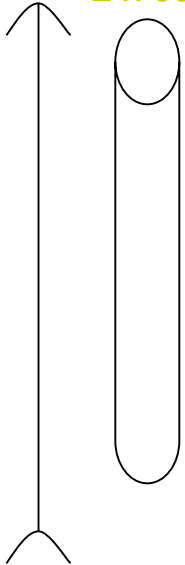


Eye Error:
-2 x 080

With this orientation of the cross, the focal lines become **longer**, which makes the Circle of Least Confusion **larger**.

Resultant:
+.35 x 130
-.35 x 040

+2 x 090

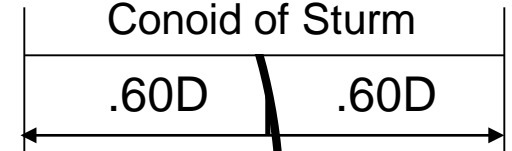


The image thus becomes **more blurry** to the patient.

Conoid of Sturm

.60D

.60D



+.25 x 130
-.25 x 040

↑
Jackson Cross

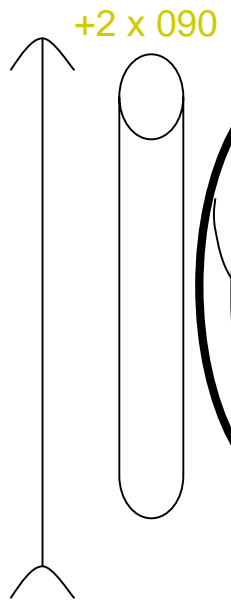
Astigmatic Correction: *Jackson Cross*



Eye Error:
-2 x 080

With this orientation of the cross, the focal lines become **longer**, which makes the Circle of Least Confusion **larger**.

Resultant:
+.35 x 130
-.35 x 040

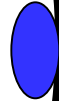
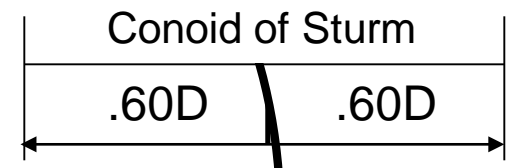


+.25 x 130
-.25 x 040

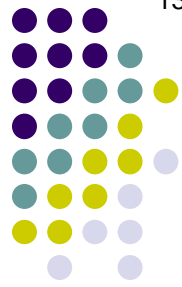
↑
Jackson Cross

The image thus becomes **more blurry** to the patient.

Flip the Jackson cross.



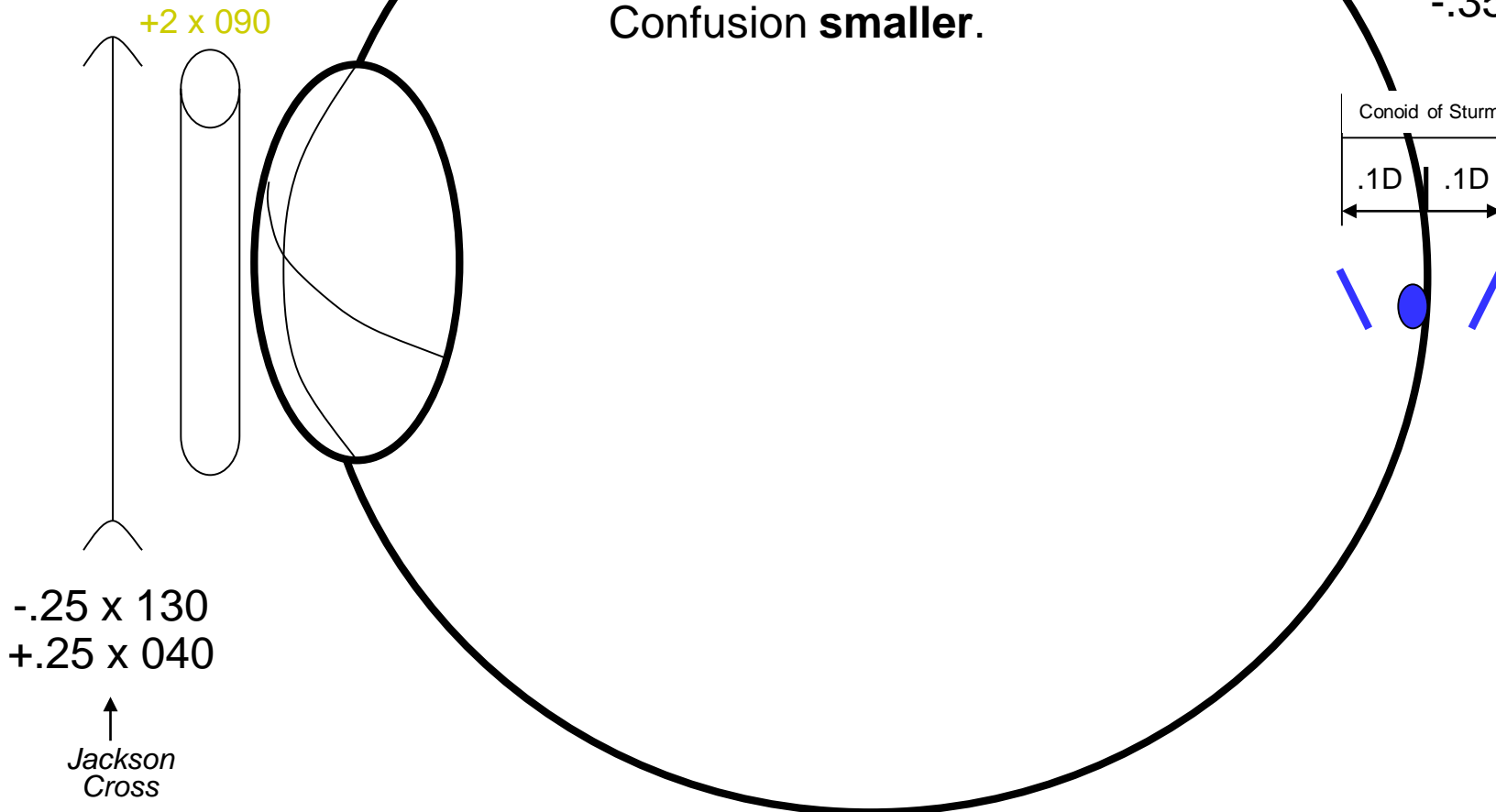
Astigmatic Correction: *Jackson Cross*



Eye Error:
-2 x 080

In this orientation, the focal lines become **shorter**, which makes the Circle of Least Confusion **smaller**.

Resultant:
+.35 x 130
-.35 x 040



Astigmatic Correction: *Jackson Cross*

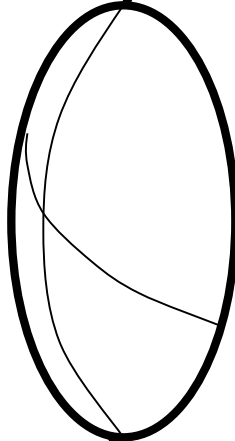
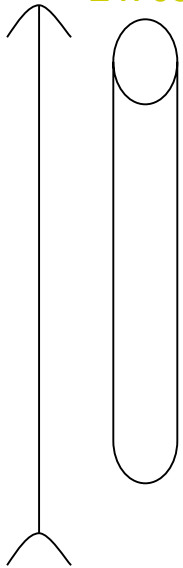


Eye Error:
-2 x 080

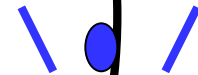
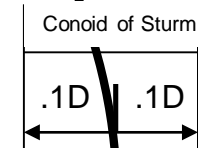
In this orientation, the focal lines become **shorter**, which makes the Circle of Least Confusion **smaller**.

Resultant:
+.35 x 130
-.35 x 040

+2 x 090



Because this is less blurry,
the cylinder axis is rotated 10°
toward the plus.



-.25 x 130
+.25 x 040

↑
*Jackson
Cross*

Astigmatic Correction: *Jackson Cross*

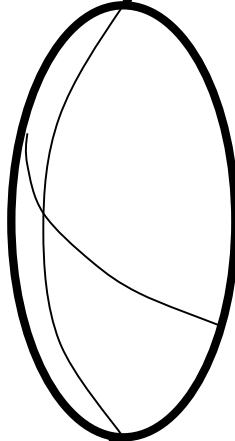
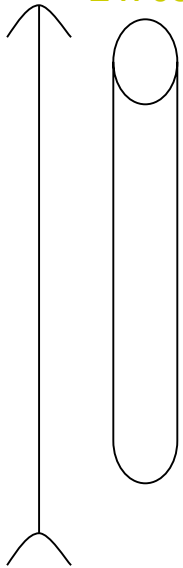


Eye Error:
-2 x 080

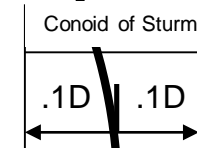
In this orientation, the focal lines become **shorter**, which makes the Circle of Least Confusion **smaller**.

Resultant:
+.35 x 130
-.35 x 040

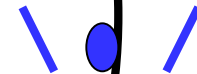
+2 x 080



Because this is less blurry, the cylinder axis is rotated 10° toward the plus.



The Jackson cross is reintroduced.



-.25 x 130
+.25 x 040

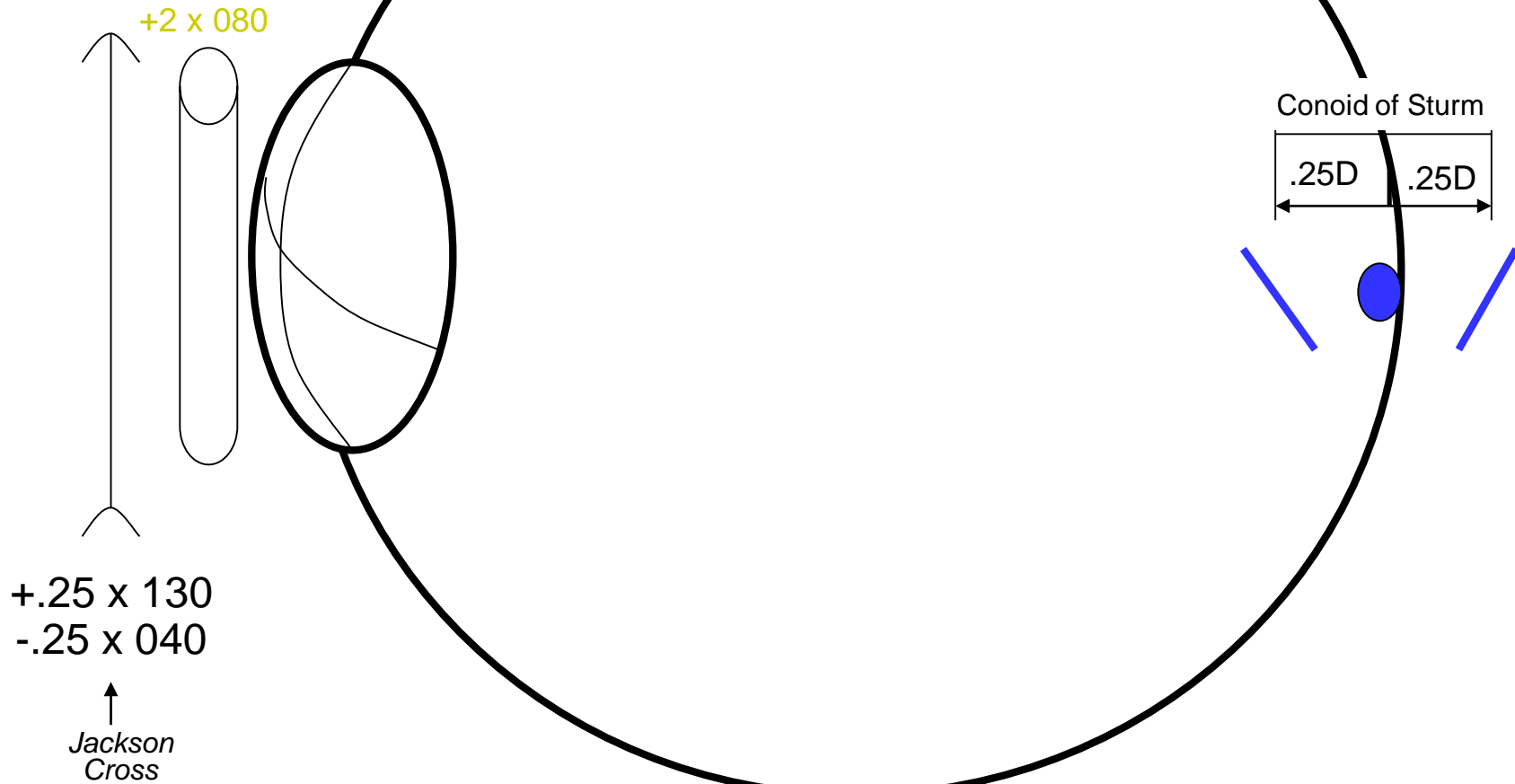
↑
Jackson Cross

Astigmatic Correction: *Jackson Cross*



Eye Error:
 -2×080

Now the only error present
is due to the Jackson cross
cylinder itself.



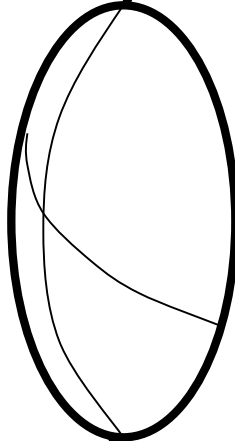
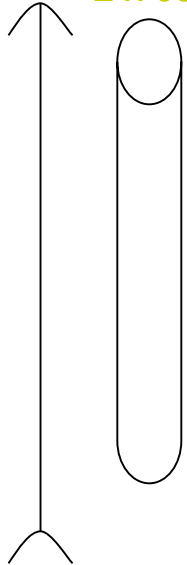
Astigmatic Correction: *Jackson Cross*



Eye Error:
-2 x 080

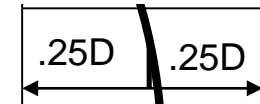
Now the only error present is due to the Jackson cross cylinder itself.

+2 x 080



As the Jackson cross is flipped, the positions of the focal lines reverse, but the Circle of Least Confusion does not change in size.

Conoid of Sturm



-0.25 x 130
+0.25 x 040

↑
Jackson Cross

Astigmatic Correction: *Jackson Cross*

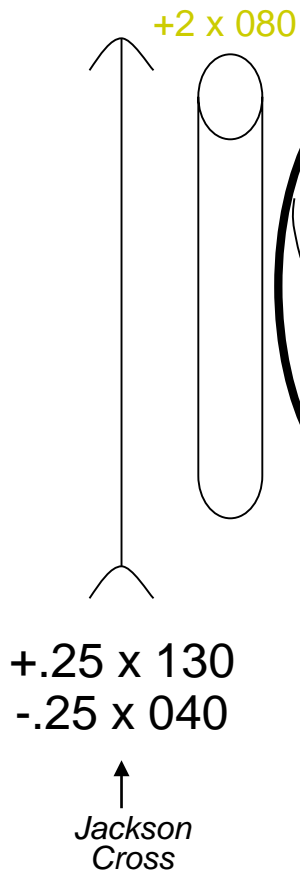


Eye Error:
-2 x 080

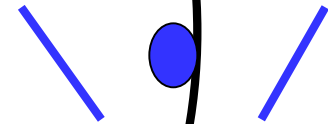
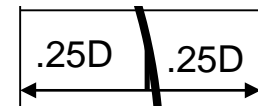
Now the only error present is due to the Jackson cross cylinder itself.

As the Jackson cross is flipped, the positions of the focal lines reverse, but the Circle of Least Confusion does not change in size.

Because the Circle does not change in size, the patient perceives the two positions as equally blurry, and we know the correct axis has been found.



Conoid of Sturm



Astigmatic Correction: *Jackson Cross*



- So that's how **Jackson Cross** refraction works!

| | <i>Retinoscopic</i> | <i>Jackson Cross</i> |
|---------------|---|--|
| <i>Step 1</i> | Use sphere to place one focal line on the retina | Use sphere to place the CoLC on the retina |
| <i>Step 2</i> | Use cylinder to place the other focal line on the retina | Use cross to simultaneously collapse both focal lines |
| <i>Result</i> | Conoid collapsed to a point on the retina | Conoid collapsed to a point on the retina |