Ophthalmic Prescriptions and Refractive Errors
Timothy A. Wingert, OD, FAAO

Emmetropia
An eye that focuses parallel light rays precisely on the retina

Ametropia
An eye that does not focus light rays precisely on the retina
Myopia or Nearsightedness

An eye that focuses light rays in front of the retina

Myopia or Nearsightedness

• Axial length is too long
• Too much plus power is generated by the eye

Myopia or Nearsightedness

• Patient notices blurry distance vision
Myopia or Nearsightedness

A concave, minus, diverging lens can correct the focus.

Hyperopia or Farsightedness

An eye that focuses light rays behind the retina.

Hyperopia or Farsightedness

- Axial length is too short
- Not enough plus power is generated by the eye.
Hyperopia or Farsightedness

• Patient notices near vision is not as clear as distance

Hyperopia or Farsightedness

A convex, plus, converging lens can correct the focus

Hyperopia or Farsightedness

Crystalline lens can also change shape to provide more plus power
Astigmatism

Light rays don’t come to a single focus

Astigmatism

- Light rays don’t hit a spherical surface
- Can be caused by the cornea or crystalline lens

Astigmatism

- Patient notices blurry vision at all distances
Astigmatism

42.50 @ 180 / 43.50 @ 90
1.00D of corneal astigmatism

-3.00 1.00 x 180

43.00 @ 180 / 43.25 @ 90
-3.00 1.00 x 180
Astigmatism

A cylinder lens set at a specific axis is needed to correct for both meridians of power.

Refractive Media

- Cornea
- Crystalline Lens

Accommodation

- Ciliary muscle contracts and zonules, or suspensory ligaments, relax causing accommodation
- Crystalline lens becomes more convex and gains plus power
Presbyopia

- Crystalline lens gradually hardens
- Muscles that hold the lens in place become weaker
- Diminished accommodation is called presbyopia

Presbyopia

- Bifocal or multifocal lenses are needed along with the regular distance correction
- Add power is the same for each eye
- Quarter diopter increments between +1.00D and +2.50D

Anisometropia

OD +2.00D
OS +8.00D

When the eyes have unequal refractive powers
Anisometropia

- Contact lenses
- Patching

When the eyes have unequal refractive powers

Aniseikonia

May be the result of a large refractive difference between the two eyes or by the Rx in eyeglasses

When the image seen by one eye is larger than the image seen by the other eye

Normalizing the image size received by the brain is most often done through the use of contact lenses

When the image seen by one eye is larger than the image seen by the other eye
Antimetropia

When one eye is myopic and the other is hyperopic

OD: -3.00D
OS: +2.00D

Sphere Power

<table>
<thead>
<tr>
<th>Sphere</th>
<th>Cylinder</th>
<th>Axis</th>
</tr>
</thead>
<tbody>
<tr>
<td>-3.00D</td>
<td>---</td>
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</table>

- Sphere power only
- All 360 degrees of the lens has the same power
**Sphere Power**

<table>
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- Minus powers represent myopia
- Two prisms apex to apex
- Minus power lenses are thinner in the center, thicker on the edge (concave)
- Minify objects

**Sphere Power**

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- Plus powers represent hyperopia
- Two prisms base to base
- Plus power lenses are thicker in the center, thinner on the edge (convex)
- Magnify objects
Effective Power

- All lenses have two power values
- Actual power, measured by the lensometer
- Effective power the wearer perceives

Vertex distance
Cylinder Power

<table>
<thead>
<tr>
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<tbody>
<tr>
<td>-3.00D</td>
<td>-1.25D</td>
<td>180</td>
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</table>

- Sphero-cylindrical correction
- Two major meridians of power with a gradation of powers between

Cylinder Power

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<tr>
<td>+2.75D</td>
<td>-0.75D</td>
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<td>-4.00D</td>
<td>+1.00D</td>
<td>90</td>
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- Sphero-cylindrical correction
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**Cylinder Power**

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- Sphero-cylindrical correction
- Two major meridians of power with a gradation of powers between

**Cylinder Power**

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<td>-4.00D</td>
<td>+1.00D</td>
<td>90</td>
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</table>

- Sphero-cylinder correction
- Two major meridians of power with a gradation of powers be between

**Add Power**

<table>
<thead>
<tr>
<th>Sphere</th>
<th>Cylinder</th>
<th>Axis</th>
<th>Add</th>
</tr>
</thead>
<tbody>
<tr>
<td>-4.00D</td>
<td>+1.00D</td>
<td>90</td>
<td>+1.50</td>
</tr>
</tbody>
</table>

- Add powers indicate presbyopia
- Young people can accommodate up to 14.00D
- By the age of 45, accommodation drops to 4.00D
- Accommodation is only 2.00D at age 50
### Add Power

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</tr>
</thead>
<tbody>
<tr>
<td>-3.00D</td>
<td>-1.00D</td>
<td>180</td>
<td>+1.50</td>
</tr>
</tbody>
</table>

**Distance**

-3.00 -1.00 x 180
+1.50

**Near**

-1.50 -1.00 x 180

---

### Add Power

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<th>Cylinder</th>
<th>Axis</th>
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</tr>
</thead>
<tbody>
<tr>
<td>-2.00D</td>
<td>-0.25</td>
<td>180</td>
<td>+2.00</td>
</tr>
</tbody>
</table>

**Distance**

-2.00 -0.25 x 180
+2.00

**Near**

plano -0.25 x 180

---

### Add Power

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<tr>
<th>Sphere</th>
<th>Cylinder</th>
<th>Axis</th>
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</tr>
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<tbody>
<tr>
<td>+1.50</td>
<td>-0.50</td>
<td>180</td>
<td>+2.00</td>
</tr>
</tbody>
</table>

**Distance**

+1.50 -0.50 x 180
+2.00
Add Power

<table>
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<th>Sphere</th>
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<td>+1.50</td>
<td>-0.50</td>
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<td>+2.00</td>
</tr>
</tbody>
</table>

Distance

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>+1.50</td>
<td>-0.50 x 180</td>
</tr>
<tr>
<td>+2.00</td>
<td>Near</td>
</tr>
<tr>
<td>+3.50</td>
<td>-0.50 x 180</td>
</tr>
</tbody>
</table>

The New Prescription

- Lens power
- Lens material
- Lens design
- Frame size
- Frame shape

Lens Material

- Index of refraction
- Specific gravity
- ABBE value
Index of Refraction

- Determines lens thickness
- Ratio of the speed of light in air compared to the speed of light in the medium
- Higher refractive index numbers will bend light more and require less curve to achieve a specific lens power

<table>
<thead>
<tr>
<th>Material</th>
<th>Refractive Index</th>
</tr>
</thead>
<tbody>
<tr>
<td>CR-39</td>
<td>1.49</td>
</tr>
<tr>
<td>Crown Glass</td>
<td>1.523</td>
</tr>
<tr>
<td>Trivex</td>
<td>1.53</td>
</tr>
<tr>
<td>Polycarbonate</td>
<td>1.59</td>
</tr>
<tr>
<td>High Index plastic</td>
<td>1.60 - 1.70</td>
</tr>
<tr>
<td>High Index glass</td>
<td>1.60 - 1.80</td>
</tr>
</tbody>
</table>

Specific Gravity

- The measure of a lens material's weight
- The ratio of the material density to the density of water
### Specific Gravity

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</tr>
</thead>
<tbody>
<tr>
<td>CR-39</td>
<td>1.49</td>
<td>1.32</td>
</tr>
<tr>
<td>Crown Glass</td>
<td>1.523</td>
<td>2.54</td>
</tr>
<tr>
<td>Trivex</td>
<td>1.53</td>
<td>1.11</td>
</tr>
<tr>
<td>Polycarbonate</td>
<td>1.59</td>
<td>1.20</td>
</tr>
<tr>
<td>High Index plastic</td>
<td>1.60 - 1.70</td>
<td>1.34 - 1.46</td>
</tr>
<tr>
<td>High Index glass</td>
<td>1.60 - 1.80</td>
<td>2.60 - 3.66</td>
</tr>
</tbody>
</table>

### ABBE Value
- Measure of chromatic aberration
- Refers to optical clarity
- More perceptible in higher powers and when the eye looks through the periphery of the lens

### Abbé Value
- Desire a high Abbé value in lens material
- With lower values you get more dispersion
- Some patients may notice this as color fringes in the visual field
### ABBE Value

<table>
<thead>
<tr>
<th>Material</th>
<th>Refractive Index</th>
<th>Specific Gravity</th>
<th>ABBE Value</th>
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<tbody>
<tr>
<td>CR-39</td>
<td>1.49</td>
<td>1.32</td>
<td>58</td>
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<tr>
<td>Crown Glass</td>
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<td>2.54</td>
<td>59</td>
</tr>
<tr>
<td>Trivex</td>
<td>1.53</td>
<td>1.11</td>
<td>46</td>
</tr>
<tr>
<td>Polycarbonate</td>
<td>1.59</td>
<td>1.20</td>
<td>29</td>
</tr>
<tr>
<td>High Index plastic</td>
<td>1.60 - 1.70</td>
<td>1.34 - 1.46</td>
<td>33 - 42</td>
</tr>
<tr>
<td>High Index glass</td>
<td>1.60 - 1.80</td>
<td>2.60 - 3.66</td>
<td>25 - 42</td>
</tr>
</tbody>
</table>

### Reflectance ($\rho$)

- **Light incident upon a material may be:**
  - **Reflected** (hi-index lenses reflect more than Crown or CR-39)
  - **Transmitted** – clear materials, similar to visible spectrum
  - **Absorbed** – loss of light as passed through lens

- **Typical ophthalmic lens reflects 8% or more of incident light (non-coated surface)**
- **Transmittance ($\tau$)** – fraction of incident light passing through lens
  - Varies for wavelengths, esp. for tinted lenses

### Surface Reflections Vary According to Lens Refractive Index

<table>
<thead>
<tr>
<th>Lens Material</th>
<th>Refractive Index ($n$)</th>
<th>% Reflection Front Surface</th>
<th>% Reflection Back Surface</th>
<th>Total % Reflected Both Surfaces</th>
<th>Total % of Light Transmitted</th>
</tr>
</thead>
<tbody>
<tr>
<td>CR-39 plastic</td>
<td>1.498</td>
<td>3.98</td>
<td>3.82</td>
<td>7.8</td>
<td>92.2</td>
</tr>
<tr>
<td>Crown Glass</td>
<td>1.523</td>
<td>4.30</td>
<td>4.11</td>
<td>8.4</td>
<td>91.6</td>
</tr>
<tr>
<td>Trivex</td>
<td>1.532</td>
<td>4.4</td>
<td>4.12</td>
<td>8.6</td>
<td>91.4</td>
</tr>
<tr>
<td>Polycarbonate</td>
<td>1.586</td>
<td>5.13</td>
<td>4.87</td>
<td>10.0</td>
<td>90.0</td>
</tr>
<tr>
<td>High-index Plastic</td>
<td>1.66</td>
<td>6.16</td>
<td>5.78</td>
<td>12.0</td>
<td>88.0</td>
</tr>
<tr>
<td>High-index Plastic</td>
<td>1.74</td>
<td>7.29</td>
<td>6.76</td>
<td>14.1</td>
<td>85.9</td>
</tr>
</tbody>
</table>
Ultraviolet Transmittance

- Described in terms of
  - % UVA and UVB transmittance
  - the wavelength cutoff
  - Or the % transmittance at 380 nm.
- Polycarbonate does not transmit UV radiation
  (no / negligible amt. wavelengths below 380nm)
- Most high-index plastic lens materials absorb 100% of UVB radiation and 98% of UVA
- UV exposure is cumulative throughout life
  - Children higher exposure

Comparison of Properties

<table>
<thead>
<tr>
<th>Material</th>
<th>Index</th>
<th>Abbe Value</th>
<th>Specific Gravity</th>
<th>UV Transmission</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crown</td>
<td>1.523</td>
<td>58.5</td>
<td>2.54</td>
<td>87%</td>
</tr>
<tr>
<td>CR-39 Plastic</td>
<td>1.49</td>
<td>57.8</td>
<td>1.32</td>
<td>43%</td>
</tr>
<tr>
<td>Polycarbonate</td>
<td>1.586</td>
<td>30</td>
<td>1.20</td>
<td>0 - 1%</td>
</tr>
<tr>
<td>1.7 Glass index</td>
<td>1.701</td>
<td>30.8</td>
<td>2.99</td>
<td>57%</td>
</tr>
<tr>
<td>Trivex®</td>
<td>1.532</td>
<td>43.45</td>
<td>1.11</td>
<td>0% (394nm cutoff)</td>
</tr>
</tbody>
</table>

Glass Material - Impact Resistance

- Glass must be treated (tempered) to pass the FDA test.
- Places outer surface in a state of compression.
- **Heat Treatment (Thermal Tempering)**
- **Chemical Tempering**
- Loses impact resistance when scratched
Glass Material - Impact Resistance

- **Heat Treatment (Thermal Tempering)**
  - Layer of surface compression approximately 600μm thick.
  - 2-3X more impact resistant than untempered glass.

Heat / Thermal Tempering

- Heat lens to softening point
- Rapidly cool with blasts of air
- Outer surface cools quicker than inner: outer surface in state of compression, inner in state of tension.
- Material become birefringent: evaluated with polarized filters (colmascope).
- Again,
  - Layer of surface compression approximately 600μm thick.
  - 2-3X more impact resistant than untempered glass.

Chemical Tempering

- Exchanging larger ions from a heated salt bath for smaller ions from the surface of the lens (i.e.: K+ for Na+)
- Places the surface in a state of compression.
- Takes 4 – 16 hours

- Layer of compression at the surface 75μm thick.
- 7-10X more impact resistant than untempered glass.
Glass Material - Impact Resistance

- Scratches on lens surface – **Reduces Impact Resistance**!
  - Consider how a glass is scored to break along line
  - Scratch is a weak spot on lens like a fault line
  - Back surface scratches reduce > front surface scratches
    - Front surface reduced Impact Resistance by 20%
    - Back surface by 80%

Plastic Material – Impact Resistance

- Inherently more impact resistant material – softer
- No “tempering” required
- Lenses can be batch tested, unless altered

Plastic Material – Impact Resistance

- Scratch and Anti-reflective coatings **DECREASE** impact resistance of plastic lenses!
  - Coatings are harder than the plastic lens materials
  - Lens starts to break at the weakest point
    - Lens may flex versus break, but as flexes, the coating cracks
    - Coating is strongly bonded to the lens
    - Energy concentrated in first crack is released and may cause the lens to break.
Glass versus Plastic?

- Low velocity, large mass objects (softball) chemically tempered glass performs better than CR-39
- Smaller, high velocity, sharply pointed objects, CR-39 outperforms chem tempered glass.
- Other materials outperform both

IMPACT RESISTANCE

Again,

- Glass lenses must be tested individually
- Plastic Lenses may be batch tested.

- Batch testing not allow if:
  - the lens is surfaced less than minimal thickness
  - is altered after received from manufacture (i.e. getting AR coat at lab, then the AR lab will batch test.)

- FDA Record keeping requirements - 3 years

Factors Affecting Impact Resistance of Lens

- Lens Scratches
- Lens Coatings
IMPACT RESISTANCE

- Polycarbonate
- Not unbreakable or shatter-proof!!
In Summary
An Ideal Lens would have
- HIGH Index of Refraction
- HIGH Abbe Value
In Summary
An Ideal Lens would have

- HIGH Index of Refraction
- HIGH Abbe Value
- LOW Specific Gravity
- LOW UV transmittance
- HIGH Impact Resistance
Which lens material has the lowest specific gravity?

1. CR-39
2. Crown glass
3. Trivex
4. High index plastic

Lens Design

- Free-form technology is the state-of-the-art in lens design and manufacturing
  - Lens design
  - Software
  - Specialized equipment

Why Free-form Lenses?

- Used to manufacture all varieties of lenses designs
  - Single vision
  - Aspheric
  - Bifocal
  - Progressive
  - Improved vision at all distances
Free-form Lens Designs

- Free-form lenses are not limited by set base curves
- Customized free-form lenses adjust the curves of the lens so that each wearer's prescription is optically refined
- Free-form surfacing equipment has the capability to produce greater precision and smoother surfaces

Frame Selection

- Frame size is a significant contributor to thin lens design
- Bigger frame styles results in thicker lenses at the edge for minus prescriptions and nasally for plus prescriptions.
- Smaller eye sizes result in thinner lenses

Images courtesy Barré
Frame Selection

- Matching the patient’s pupillary distance with the center of the eyewire results in the thinnest lenses

Boxing System

- The horizontal measure of the lens is commonly referred to as the eye size and is denoted as the "A" measurement

- The vertical measure is the "B" measurement
- Geometric center is where the A and B measurements intersect
Boxing System

- The distance between the nasal eyewire at its narrowest point is the bridge size

Boxing System

- Twice the distance from the geometric center to the farthest point along the eyewire is the effective diameter

Minimum Blank Size

- MBS = ED + Total Decentration
Minimum Blank Size

\[ A = 54 \text{mm} \quad \text{DBL} = 18 \text{mm} \quad \text{ED} = 56 \text{mm} \]

Patient PD = 64mm

\[ \text{MBS} = \text{ED} + \text{total decentration} \]
\[ \text{MBS} = \text{ED} + (54 \text{mm} + 18 \text{mm}) - 64 \text{mm} \]
\[ \text{MBS} = 56 \text{mm} + 8 \text{mm} \]
\[ \text{MBS} = 64 \text{mm} \]

Frame Shape

- Rounder shapes result in thinner lenses
- Shapes with long ED measurements result in thicker lenses.

Lifestyle Dispensing

- “What did you like about your old glasses?”
- “What hobbies do you enjoy?”
- “Where do you work?”
- “How often do you use a computer?”
Lifestyle Dispensing

- New eyewear should solve problems
  - Better vision
  - Better comfort
  - Better fashion