Basic Optics And Refractive Principles

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MSOL, CPOT, ABOC, COA, OSC

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Disclaimer

- Please prepare for certification testing with materials from the organization in which you want your certification granted i.e.:
- AOA
- JCAHPO
- ABO
- NCLE
- OT

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Outline

- The Visual System
  - Physiology
  - Ametropias
- Ophthalmic Lenses
  - Properties of Light
    - UV, Visible, and Infrared Spectrums
    - Reflection, Refraction, & Absorption
    - Aberrations
  - Lens Designs
    - Fitting
- Basic Optical Formulas

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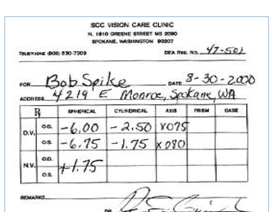
Prescriptions

- **Components**
  - Sphere, cylinder, axis
  - Add power
  - Prism
  - Prism base direction
- **Ordering**



SCC VISION CARE CLINIC
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TELEPHONE (509) 530-7309 DEA Reg. No. 47-501

FOR Bob Spike DATE 8-30-2000
ADDRESS 4219 E Monroe, Spokane, WA

℞		SPHERICAL	CYLINDRICAL	AXIS	PRISM	BASE
D.V.	O.D.	-6.00	-2.50	x075		
	O.S.	-6.75	-1.75	x080		
N.V.	O.D.	+1.75				
	O.S.					

REMARKS

DR.

What is the Abbe or V-Value of a lens?

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Minus and Plus lens

- Minus lens produce a virtual image
- Corrects for myopia
- Thinner in the middle
- Diverges light rays
- Minifies images
- Apex to apex lens
- Produce virtual focal points
- Cylinder power on the backside of lens

- Plus lens produce a real image
- Corrects for hyperopia
- Thicker in the middle
- Converges light rays
- Magnifies images
- Base to base lens
- Produces a real focal point

Info only slide

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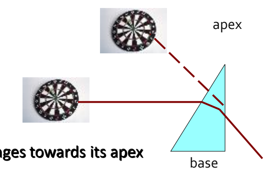
Ophthalmic Lenses

Properties of Light

Refraction - Prism

Prism bends light towards its base…



…but displaces images towards its apex

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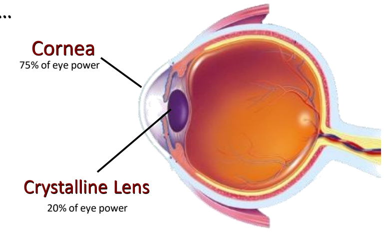
The Visual System

There are two main refractive bodies in the human eye…



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The Visual System

Cornea

The cornea is the primary refractive element in the eye…

… with a power of around +42-44 diopters

Keratometry readings

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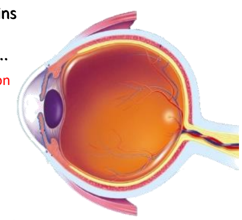
The Visual System

Cornea

The tear film maintains both the health and optics of the cornea…

Tears can impact your vision
Up to 2 diopters of power



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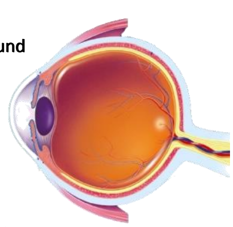
The Visual System

Crystalline Lens

The crystalline lens has a power of around +12-18 diopters…

…it is primarily responsible for changing the eye's focal point…a term referred to as accommodation



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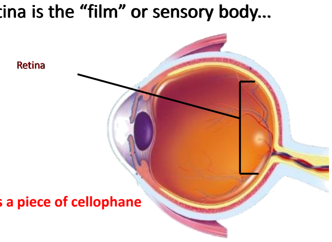
The Visual System

The retina is the "film" or sensory body…



10 layers, but as thick as a piece of cellophane

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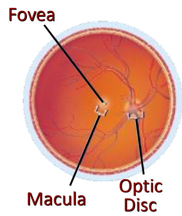
The Visual System

Retina

Light is converted to electrical impulses which are sent through the optic nerve...

...the "blind spot" is the point at which the optic nerve connects



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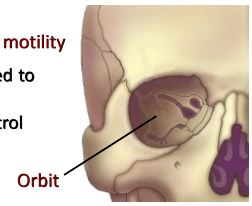
The Visual System

Eye Movement or ocular motility

The eye is connected to the orbit by several muscles which control movement...



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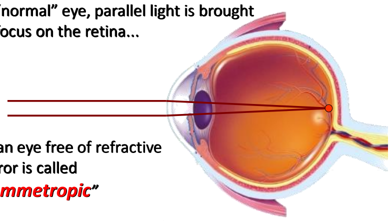
Visual Anomalies

Ametropias

In a "normal" eye, parallel light is brought to a focus on the retina...



...an eye free of refractive error is called ***"emmetropic"***

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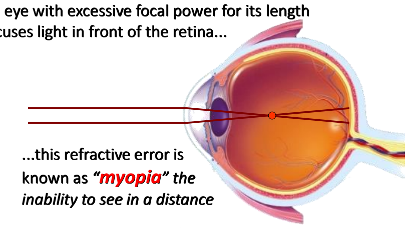
Visual Anomalies

Ametropias

An eye with excessive focal power for its length focuses light in front of the retina...



...this refractive error is known as ***"myopia"*** *the inability to see in a distance*

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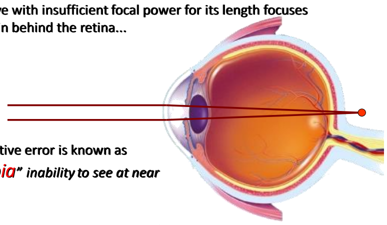
Visual Anomalies

Ametropias

An eye with insufficient focal power for its length focuses light in behind the retina...



...this refractive error is known as ***"hyperopia"*** *inability to see at near*

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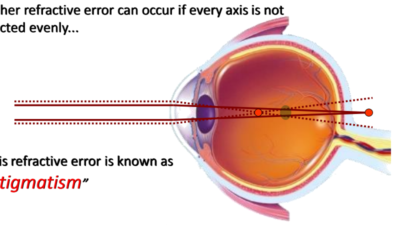
Visual Anomalies

Ametropias

Another refractive error can occur if every axis is not refracted evenly...



...this refractive error is known as *"astigmatism"*

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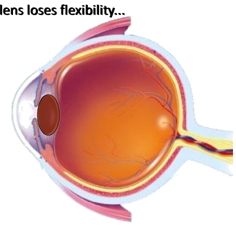
Visual Anomalies

As the eye ages, the crystalline lens loses flexibility...

Ametropias



...this results in a condition known as *"presbyopia"*

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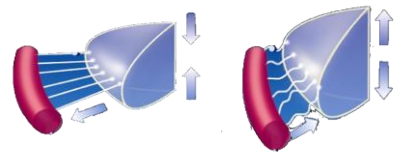
Visual Anomalies

Presbyopia

The inability to focus on near objects becomes noticeable around age 40 and steadily worsens thereafter...



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Ophthalmic Lenses

- Ophthalmic Lenses
  - Properties of Light
    - UV, Visible, and Infrared Spectrums
    - Reflection, Refraction, & Absorption
  - Lens Designs
  - Lens Materials
  - Index of refraction

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Ophthalmic Lenses

Properties of Light

Like the artist's paint, the eye requires light to see...

...what is the speed of light in a vacuum? 186,000 mps

...what is "light," and how does it work?

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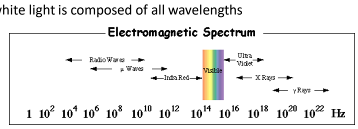
Ophthalmic Lenses

Properties of Light

So what is light?

- particles in the form of a wave
- electromagnetic radiation with **wavelengths between 400 and 700 nanometers** (a nanometer is 1/1,000,000th mm) is considered **the visible spectrum**
- white light is composed of all wavelengths



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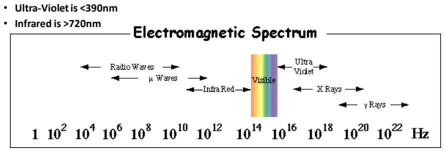
Ophthalmic Lenses

Properties of Light

So what is light?

- **Visible light** is a small portion of the overall spectrum of light (**380-760**)
- EM surrounding the visible spectrum is hazardous
  - **Ultra-Violet is <390nm**
  - **Infrared is >720nm**



What part of the spectrum is most visible to the eye?

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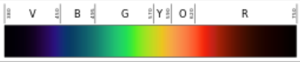

Color	Wavelength	Frequency	Photon energy
violet	380–450 nm	668–789 THz	2.75–3.26 eV
blue	450–495 nm	606–668 THz	2.50–2.75 eV
green	495–570 nm	526–606 THz	2.17–2.50 eV
yellow	570–590 nm	508–526 THz	2.10–2.17 eV
orange	590–620 nm	484–508 THz	2.00–2.10 eV
red	620–750 nm	400–484 THz	1.65–2.00 eV

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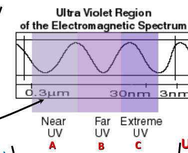
Ophthalmic Lenses

Properties of Light

Ultra-Violet Radiation

Ultraviolet is next to what color?

UVA is less photobiologically active than **UVB** and consists of light just beyond the blue end of the visible spectrum...



UVB falls farther from the visible spectrum, is the most significant UV most of us experience, and is variably absorbed by ozone...

UVC light is farthest from the visible spectrum, and is almost completely absorbed by ozone (except at very high altitudes)....

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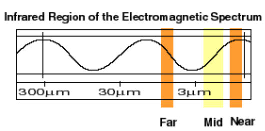
Ophthalmic Lenses

Properties of Light

Infrared

Infrared is close to what color of the spectrum?



Infrared is >720nm- the most common source is blown glass...

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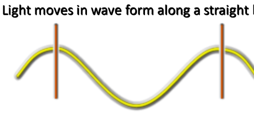
Ophthalmic Lenses

Properties of Light

Movement of Light

Light moves in wave form along a straight line...



...the distance between peaks determines the **wavelength**

Which color of the visible spectrum has the longest wavelength?

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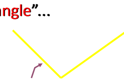
Ophthalmic Lenses

Properties of Light

Reflection

Every lens has a "critical angle"...



...light striking the lens flatter than this angle will be reflected

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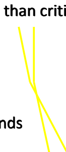
Ophthalmic Lenses

Properties of Light

Refraction

Light striking at an angle steeper than critical is refracted...



...the **amount of refraction** depends on the **amount of prism**

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Lenses: Index of Refraction

- **Definition: A comparison, or ratio, of the speed of light in air to the speed of light in another medium**
- **Is a measure of the density of the material**
- **Values**
  - Speed of light in air in a vacuum: 186,000 mps
  - Air= 1.00
  - Water= 1.33

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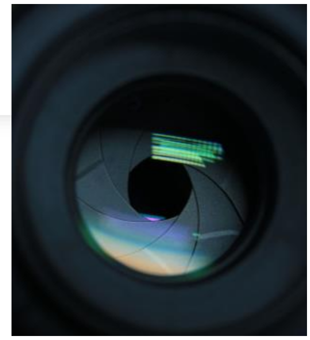
Lenses: Index of Refraction

- **Index of refraction (n)= <u>in a vacuum</u>**
  in a medium

  Speed of light in air/speed of light in material

  The higher the index of refraction, the better the optical quality of the lens



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Lens Materials: Glass

Crown glass	IR: 1.52
Flint glass	IR: 1.65
Hi-Index glass	IR: 1.9

Advantages: More scratch resistant, clearer optics
Disadvantages: Heavier, less impact resistant

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Lens Materials: Glass

Crown glass	IR: 1.52
Flint glass	IR: 1.65
Hi-Index glass	IR: 1.9

Advantages: More scratch resistant, clearer optics
Disadvantages: Heavier, less impact resistant

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Lens Materials: Plastic

CR-39	IR: 1.49
Hi-Index plastic	IR: 1.58-1.70

<u>Advantages:</u> Lighter weight, more impact resistant compared to glass, easily tinted

<u>Disadvantages</u>: More prone to scratches, less ultra-violet (UV) protection on untreated lens

What does a higher index of refraction mean?

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Polycarbonate

- 10x stronger than CR-39
- Safety glasses
- Softer lens so easier to scratch
- Higher index of refraction
- Blocks 99-100% of UV rays
- Requires coating (AR, scratch)
- Lighter than CR-39
- Thinner
- Low Abbe value – chromatic aberrations

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TriVex

- Same advantages as polycarbonate
- Lighter than polycarbonate
- Slightly lower index of refraction over poly
- 10X stronger than polycarbonate
- Optical quality better than polycarbonate
- Natural for outdoor use
- Better for computer use
- More expensive

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Place these in order from high to low for index of refraction

A. Polycarbonate
B. Crown glass
C. CR-39
D. Trivex
E. High Index 1.67

- 1. _______________
- 2_______________
- 3. _______________
- 4. _______________
- 5. _______________

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Place these in order from high to low for index of refraction

A. Polycarbonate
B. Crown glass
C. CR-39
D. Trivex
E. High Index 1.67

- 1. ___1.568_____
- 2___ 1.52______
- 3. __1.498______
- 4. __1.53______
- 5. __1.67_______

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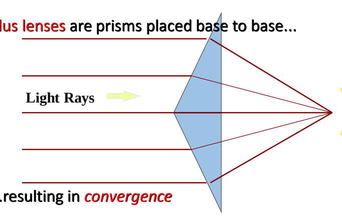
Ophthalmic Lenses

Properties of Light

Refraction - Prism

Plus lenses are prisms placed base to base...



...resulting in *convergence*

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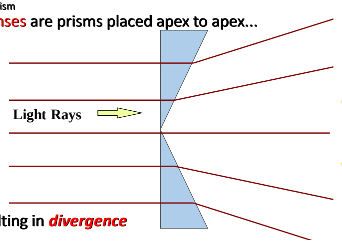
Ophthalmic Lenses

Properties of Light

Refraction - Prism

Minus lenses are prisms placed apex to apex...



...resulting in *divergence*

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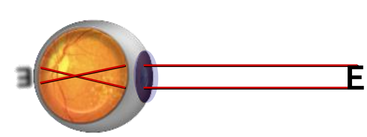
Vision & Ametropias

When light is not focused on the retina, an ametropia is present... for example, a myopic eye focuses light in front of the retina...



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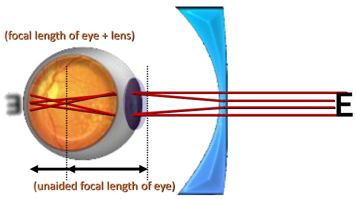
Vision & Ametropias

...a **minus** powered (**diverging**) lens shifts the focus back to the retina



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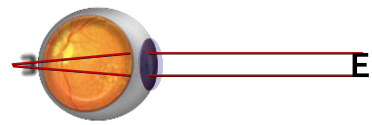
Vision & Ametropias

A **hyperopic** eye focuses light behind the retina...



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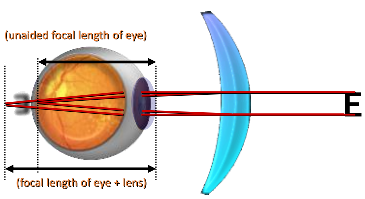
Vision & Ametropias

...a **plus** powered (**converging**) lens shifts the focus up to the retina



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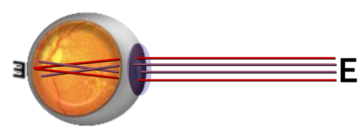
Vision & Ametropias

Astigmatism causes light along different axes to focus at different planes...



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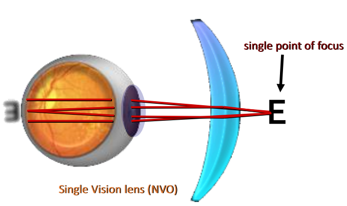
Vision & Ametropias

To restore **near vision**, the **required convergence** is supplied by a plus powered lens...



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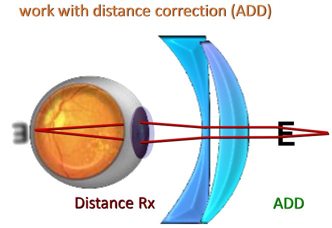
Vision & Ametropias

...this plus lens may stand alone (NVO) or may work with distance correction (ADD)



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Ophthalmic Lenses

Properties of Light

Refraction - Dispersion

Abbe value is used to describe the amount of dispersion a material will create...

...ranges are from 59 (CR-39) to 30 (polycarbonate)

Chromatic Aberration

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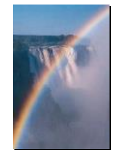
Ophthalmic Lenses

Properties of Light

Absorption

White light is composed of all colors in the rainbow- but all colors can be formed using a combination of three "primary colors:"



- Red
- Yellow
- Blue

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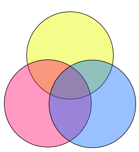
Ophthalmic Lenses

Properties of Light

Absorption

Filters absorb light. Chemical compounds are used to selectively filter single colors.



To create a green filter, only red light must be absorbed. The appropriate chemicals are applied, and a green filter is created.

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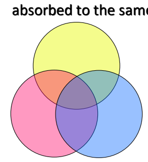
Ophthalmic Lenses

Properties of Light

Absorption

To create a perfectly neutral- or gray- filter, energy from all three primary points in the spectrum must be absorbed to the same degree.



When creating a filter by absorbing dye into resin, this process is further complicated by the inconsistent nature of the chemicals involved.

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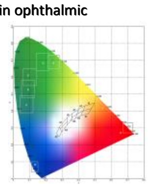
Ophthalmic Lenses

Properties of Light

Aberrations

The most common aberrations found in ophthalmic lenses are:

- **Power Error**
- **Material Distortion**
- **Marginal Astigmatism**
- **Chromatic Aberration**
- **Unwanted Prism***



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Ophthalmic Lenses

Properties of Light

Aberrations

Aberrations occur due to various factors:

- Refractive power
- Off-axis viewing of objects
  - lens tilt
  - peripheral objects
- Vertex distance
- Lens material

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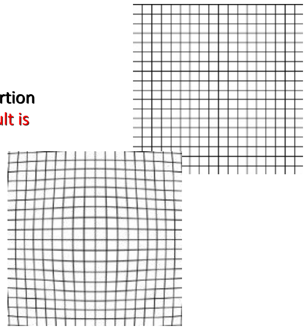
Ophthalmic Lenses

Properties of Light

Aberrations – Distortion

The minus lens result is barrel distortion...

...the periphery of an object will be minimized to a greater degree than the center



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Ophthalmic Lenses

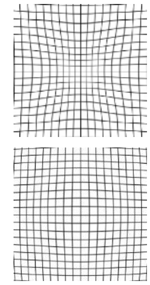
Properties of Light

Aberrations – Distortion

Plus lenses create the opposite effect...pincushion effect

Aspheric lenses reduce distortion

...the periphery of an object will be magnified to a greater degree than the center



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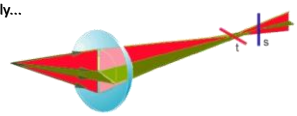
Ophthalmic Lenses

Properties of Light

Aberrations – Marginal Astigmatism

Light striking the lens at an oblique axis do not refract evenly...



...unwanted astigmatism occurs

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Ophthalmic Lenses

Properties of Light

Aberrations – Chromatic Aberration – failure of lens to focus light

As previously discussed, chromatic aberration is the dispersion of white light into its component colors...

...**large amounts of prism** are necessary for chromatic aberration to affect vision

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Ophthalmic Lenses

Properties of Light

Prism

The eye does not always view objects through the optical center...

...what will the eye perceive?

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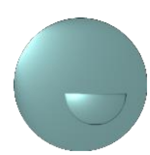
Ophthalmic Lenses

Lens Types

There are many types of lenses designed to meet specific patient needs...

- Single Vision
  - Distance Vision
  - Near & Intermediate Vision
- Bifocals
  - Flat Tops
  - Executive
- Trifocals
- Progressive Addition Lenses



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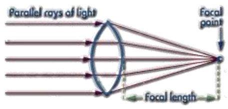
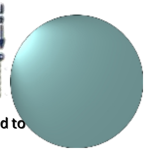
Ophthalmic Lenses

Lens Types – Single Vision

Single Vision lenses have only **one *focal length***...





...single vision lenses can be used to provide clear distance, intermediate, or near vision for presbyopes

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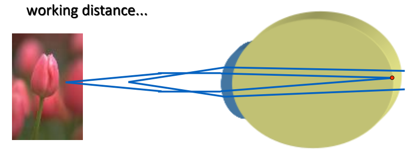
Ophthalmic Lenses

Lens Types – Single Vision

Single vision readers only provide clear vision at one working distance...



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Vertex Distance – Pantoscopic Tilt

- When the frames are moved out on a patients face
  - Minus lens get **weaker**
  - Plus lenses get **stronger**
  - **Dot the frame** where the bend is suppose to be on the patient
- Pantoscopic Tilt – the frame should be the same distance from the forehead and the cheek bone

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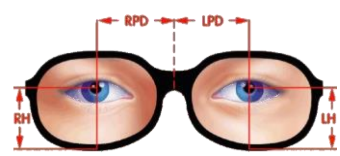
Ophthalmic Lenses

Lens Types – Single Vision

Single vision lenses require measurement of pupillary distance, and occasionally fitting height...



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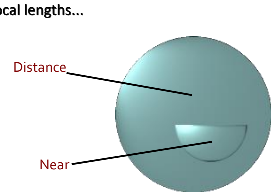
Ophthalmic Lenses

Lens Types – Bifocals

Bifocal lenses have two focal lengths...



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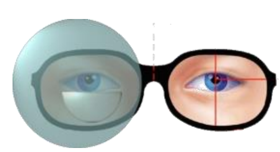
Ophthalmic Lenses

Lens Types – Bifocals

Flat-top bifocals are usually fit:

- to lower limbus (seg line @ lower lid)
- decentered 1.5mm in from Far PD



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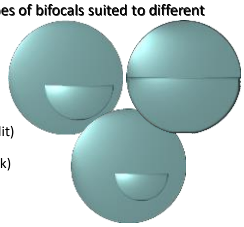
Ophthalmic Lenses

Lens Types – Bifocals

There are several types of bifocals suited to different needs...

- Flat Tops
  - FT28
  - FT35
  - FT45
  - Smart Seg*
- Curve Top (Cosmolit)
- Executive (E-Line)
- Round Seg (Kryptok)
- Blended



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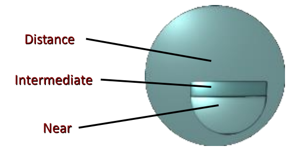
Ophthalmic Lenses

Lens Types – Trifocals

Trifocal lenses have three focal lengths...



...generally, the intermediate ADD is 50% of the near ADD

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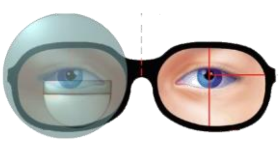
Ophthalmic Lenses

Lens Types – Trifocals

Flat-top trifocals are usually fit:

- to lower edge of the pupil
- decentered 1.5mm in from Far PD



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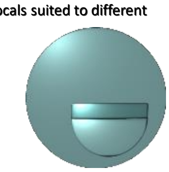
Ophthalmic Lenses

Lens Types – Trifocals

There are several types of trifocals suited to different needs...

- Flat Tops
  - FTT 7/28
  - FTT 8/35
  - Smart Seg*
- Executive (E-Line)
- Occupational*



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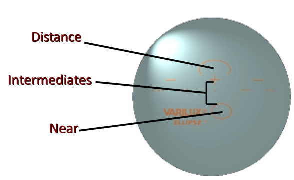
Ophthalmic Lenses

Lens Types – Progressives

Progressive Addition Lenses (PALs) have an infinite number of focal lengths across a range...



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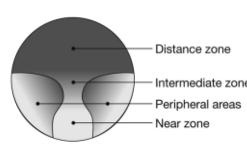

Progressive lens

Progressive Lenses

- Wide range of view
- Many different types
- Must decide what will the glasses use
- Companies: styles, labels, etc.
- Digital lenses are different

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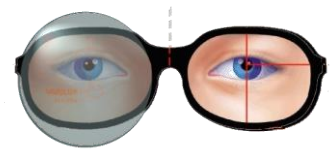
Ophthalmic Lenses (Old School)

Lens Types – Progressives

Progressives are usually fit:

- at pupil center



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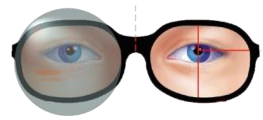
Ophthalmic Lenses

Lens Types – Progressives

PALs require precise fitting if the lens is to perform to its potential, this necessitates:

- Monocular pupillary distances
- Verification of fitting height
- Proper frame adjustment



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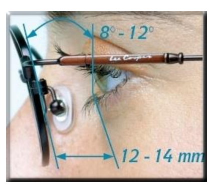
Frame Adjustment - Pantoscopic Angle

- Increase panto - bend both temples down
- Decrease panto - bend both temples up
- Increasing panto will raise the frame front height on the face; however, it will effectively lower the multifocal and vice versa



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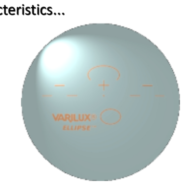
Ophthalmic Lenses

Lens Types – Progressives

There are literally hundreds of PAL designs available- each with unique characteristics...

- Traditional
  - hard design
  - soft design
  - monodesign
  - multidesign
- Short Corridor
- Customized
- Task Specific



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Lens Coatings

Polarizing filters

- Polarizing filters help eliminate unwanted light reflections off shiny surfaces such as glass or glossy coatings. Polarizing filters work like a narrow grid, allowing only waves oscillating parallel to the grid bars to pass. Light rays hitting the grid at an angle of 90° are fully blocked. Light reflected off horizontal planes is 100 percent polarized. Polarizing filters take advantage of this effect. The more the oscillating angle deviates from the grid orientation, the less light passes through the filter.

Photochromic or self-tinting lenses

- A photochromic lens changes in its transmission when exposed to UV light. The following factors influence the light transmission and darkening speed: type of light, light intensity, exposure time and lens temperature. The darkening technology is based on self-tinting molecules that change their structure. Since these molecules constantly react to the presence of UV light, the spectacle lenses perfectly adapt the tint to the light conditions

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Basic Formulas

Calculations

There are perhaps two calculations every person who works with eyewear MUST know...

- Prentice's Rule: named so after the optician Charles F. **Prentice**, is a formula used to determine the amount of induced prism in a lens: {display style P=cf/10}
- Box Measurements: In 1962 the Optical Manufacturers Association adopted the **boxing system** to provide a standard for frame and lens measurement that greatly improved upon the accuracy of previous systems. The boxing system is based upon the idea of drawing an imaginary box around a lens shape with the box's sides tangent to the outer most edges of the shape.

https://youtu.be/N7XqtoMlI8A

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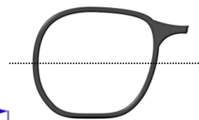
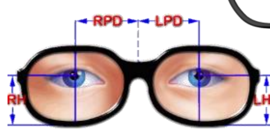
Basic Formulas

Box Measurements

Measurements of the frames- and the eye's relationship to them- should be specified…





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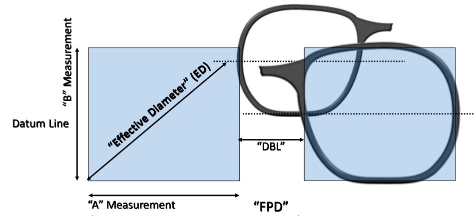
Basic Formulas

Box Measurements



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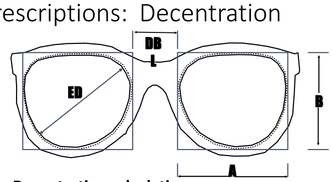
Prescriptions: Decentration



- **Decentration calculations**
  - Eye size *plus* distance between lenses *minus* patient's PD *divided* by 2
  - Example: 50-22-140 pt pd 60
  - 72 – 60 = 8 / 2 = 4

This lens is said to be 50% lighter than glass?

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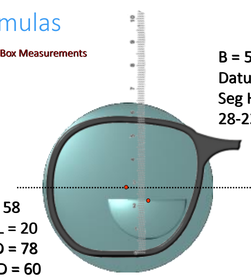
Basic Formulas

Box Measurements



B = 56
Datum (56/2) = 28
Seg Ht = 22
28-22 = 6 down

A = 58
DBL = 20
FPD = 78
NPD = 60
(78-60)/2 = 9 in

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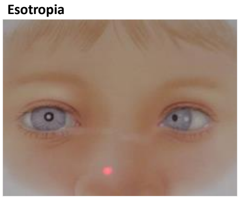
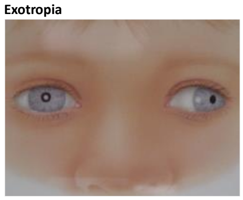
Prism

Esotropia



Base out Prism Apex In toward defect

Exotropia



Base in Prism Apex out toward defect

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Prescriptions: Verification

- **Instruments used to Verify Rx**
  - Lensometer
    - Lens power, axis, and axis location
    - Presence, amount and direction of prism
  - Geneva Lens Clock
    - Base curve
  - Colmascope or Polariscope
    - Progressive add markings
  - Calipers
    - Lens thickness

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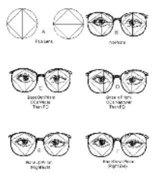
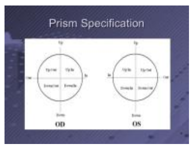
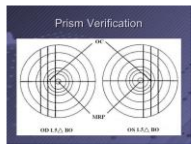
Prism Verification



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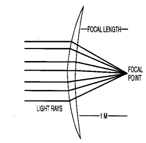
Prescriptions: Focal Length Calculations…

- **Formula: (in meters) = F=1/D**
  Focal length in meters (f) =
  1 / D (reciprocal of power in diopters)



Example: The focal length of 2.00 D lens:
f = 1 / 2.00 D f = .5 meter

Wavelength is measured from _____ to _______ of waves?

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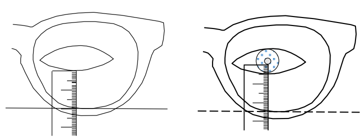
Frames: Multifocal Placement



Bifocal Seg Height **Trifocal Seg Height**

How is a progressive lens measured?

This is an old question

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Frames: Parts & Verification

- **Verification**
  - Eye wire size
  - Bridge
  - Temple length

How do you determine the frame PD?

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Troubleshooting

Problem	Lensometer	Lens Clock	PD stick
Verify Rx			
Frame adjust			
Verify OC centers			
PD			
Seg hts			
Vertex Distance			
Coatings			
Lens design			
Prism			
Warpage			
Position on the face			

- Verify the chart
- Verify SRx from provider
- Neutralized the glasses
- Use the troubleshooting guide
- 4-point stance
- Facial contact points
- Lens material
- Lens coatings
- Photochromatic/mirrors/etc.
- PPD and FPD … prismatic effect

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Thank You

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Information assistance provided by Essilor (Pete Hanlin)

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