Exam 2 Review

Concepts (CH 4 & 5)

Sign Convention

The sign convention for geometric optics assumes that light rays travel from left to right.

When using distances for objects and images:

Measurements to the left are negative.

Measurements to the right are positive.

Positive distance: *distance measured in same direction as light moves.*

Negative distance: *distance measured in opposite direction as light moves.*

Vergence / Reduced Vergence

Vergence is expressed in Diopters:

Distances are measured in meters.

1 Diopter = 1/1m

Incident Vergence (L): the vergence incident on a wave changer or lens.

Emergent Vergence (L'): the vergence of light emerging from a wave changer or lens.

Incident rays: moving toward Optical Element

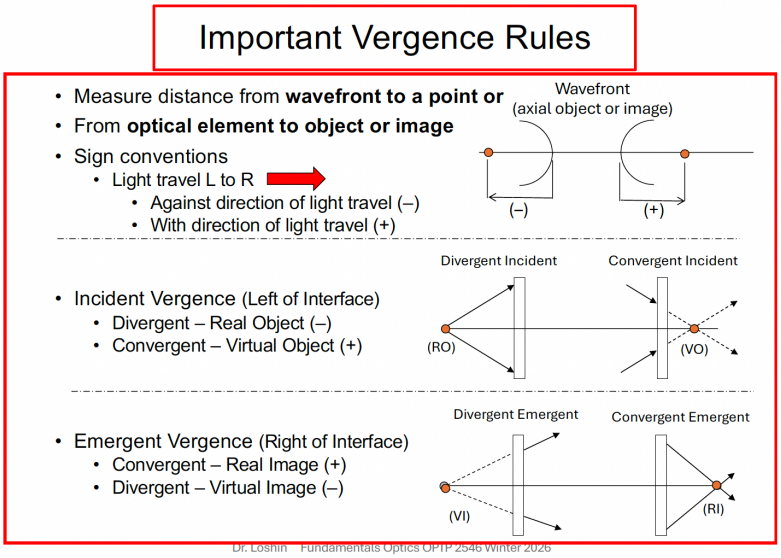
Emergent rays: leaving an Optical Element

Reduced Vergence

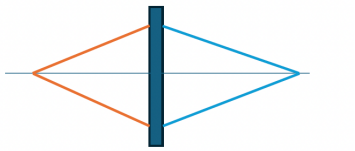
Reduced vergence depends on the index of refraction of the medium.

L = n/l (n is index of object space)

L' = n'/l' (n' is index of image space)



Power (F) of SRC



L + F = L'

Incident Vergence (n/l) + Power of Surface or Lens = Emergent Vergence (n'/l)

Positive Power = Convergence

Negative Power = Divergence

Objects & Images

Divergent Pencils
Divergent Incident Pencil: Real Object
Divergent Emergent Pencil: Virtual Image
Convergent Pencils
Convergent Incident Pencil: Virtual Object
Convergent Emergent Pencil: Real Image

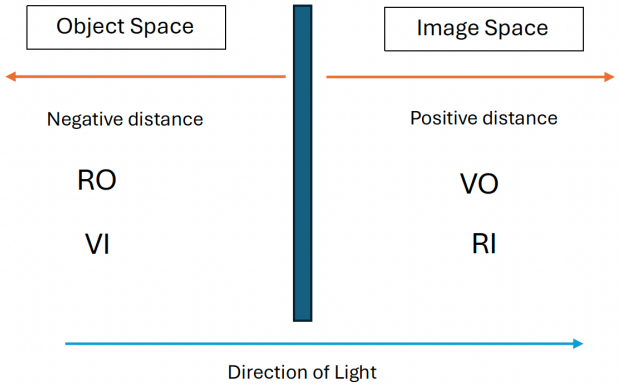
Objects & Images

Real Object: object located in Object Space
Virtual Object: object located in Image Space

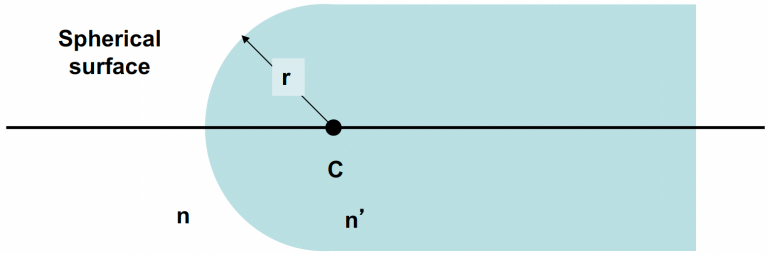
Real Image
Located in Image Space
Formed by Converging light rays
Can be formed on a screen

Virtual Image
Located in Object Space
Formed by Diverging light rays
Can not be formed on a screen

Object / Image Relationships



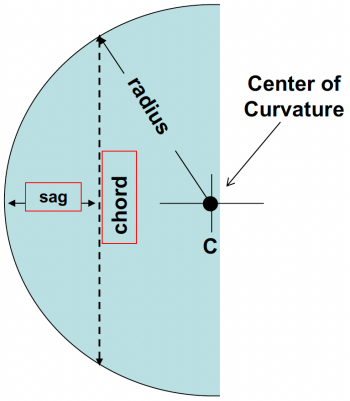
Single Refracting Surface (SRS)



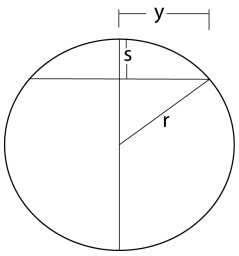
Spherical Surface

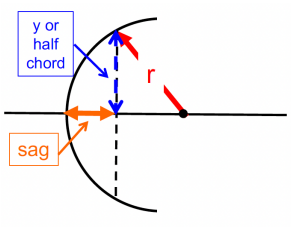
Chord – distance between any two points on the circumference of a circle

Sag – perpendicular distance from middle of chord to circumference of circle



Sagittal Depth



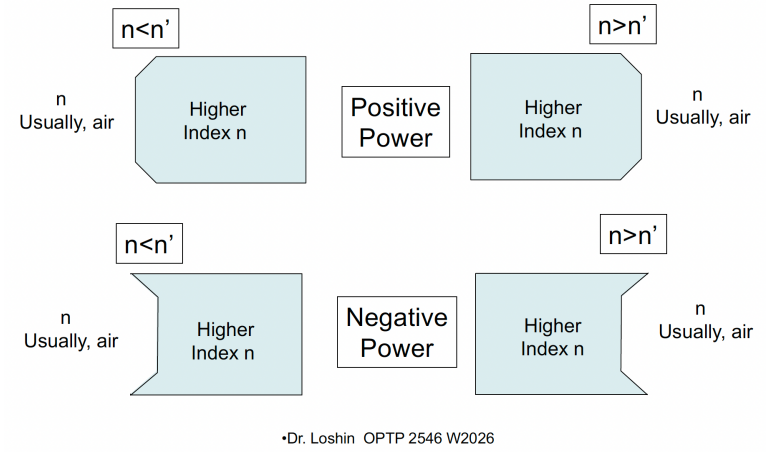


$$s = \frac{y^2}{2r}$$

Or: r = y2 / 2s r = radius of curvature
y = chord length / 2
s = sagittal depth

Surface Power

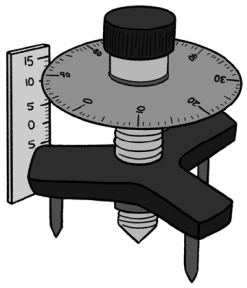
Depends on nature of curved surface (Convex or Concave)
Depends on relationship of n and n'
Remember n is index light is moving from and n' is index light is moving to

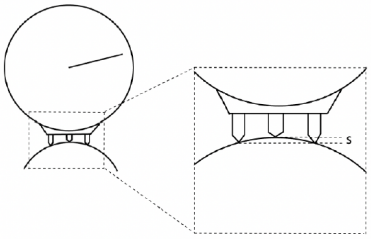


To calculate the power of a spherical surface:

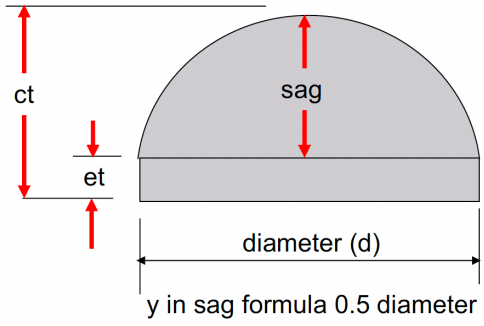
$$F = \frac{n' - n}{r}$$

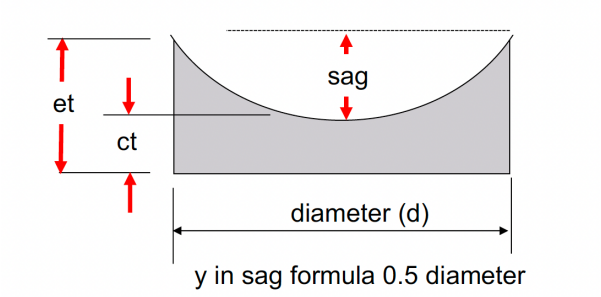
Surface Power Measurement Using Sagittal Depth



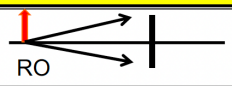
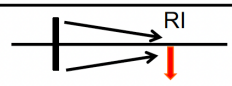
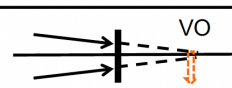


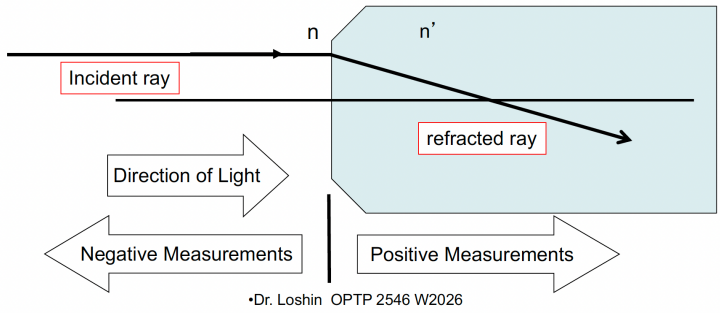
Center & Edge Thickness Calculation





Object & Image Relationships with Single Refracting Surface (SRS)

Object/Image	Symbol	Wavefront	Location	Sign Distance/ Vergence	Diagram
Real Object	RO	Divergent Incident	Left of Interface	Negative	
Real Image	RI	Convergent Emergent	Right of Interface	Positive	
Virtual Object	VO	Convergent Incident	Right of Interface	Positive	
Virtual Image	VI	Divergent Emergent	Left of Interface	Negative	



Incident Vergence (L) + Power (F) = Emerging Vergence (L')

$L + F = L'$

$$Incident\ Reduced\ Vergence = L = \frac{Index\ space\ in\ front}{object\ distance} = \frac{n}{\ell}$$

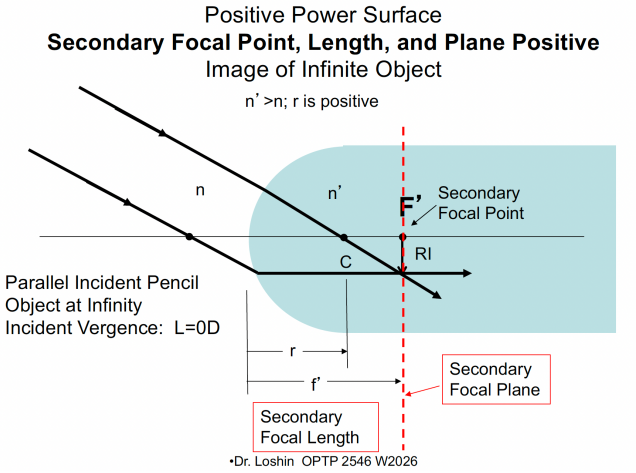
$$Emergent\ Reduced\ Vergence = L' = \frac{Index\ space\ behind}{image\ distance} = \frac{n'}{\ell'}$$

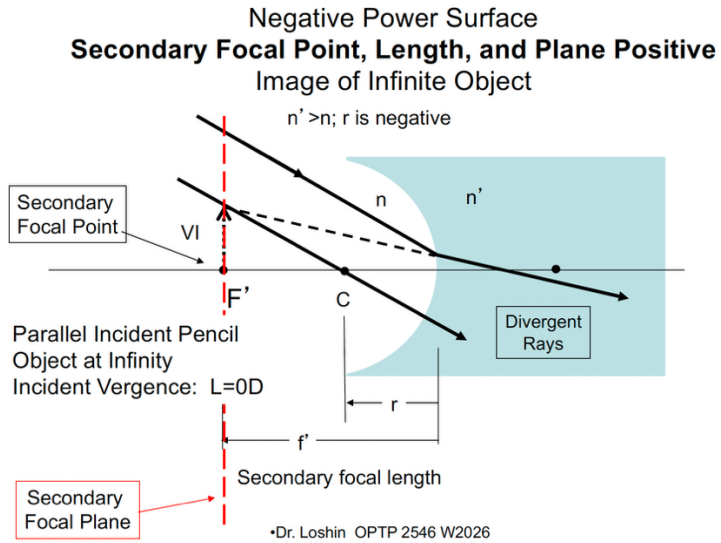
Primary & Secondary Focal Points

Positive Power Surface
- Infinite object
  - Image formed in image spaced (to right of surface)
- Real Image Formed
- Secondary Focal Length Positive (f')

Negative Power Surface
- Infinite object
  - Image formed in object space (to left of surface)
  - Virtual Image Formed
  - Secondary Focal Length Negative (f')

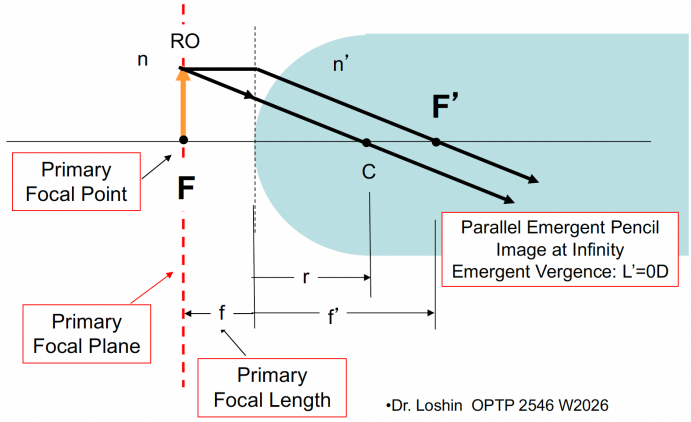
Secondary Focal Point





Primary Focal Point

Positive Power Surface
Primary Focal Point, Length, and Plane Positive
Object Location When Image at Infinity
n' >n; r is positive



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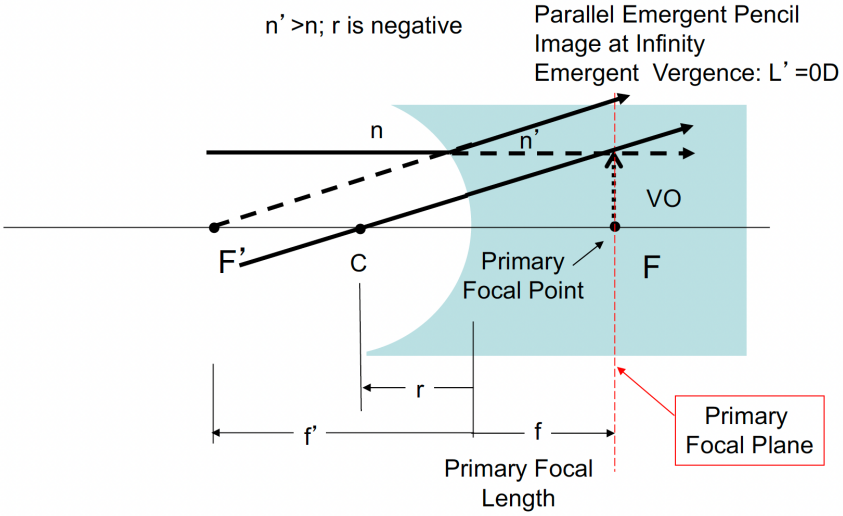
Negative Power Surface
Primary Focal Point, Length, and Plane Positive
Object Location When Image at Infinity
n' >n; r is negative



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Lateral Magnification

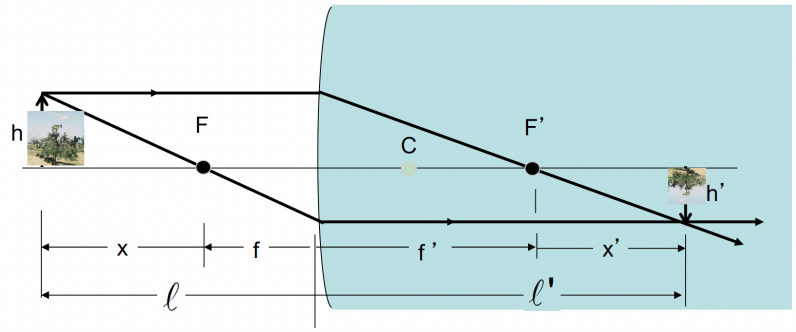
Lateral Magnification (LM) is the ratio of image size to object size

$$LM=\frac{h'}{h}=\frac{n\ell'}{n'\ell}$$

Where h is object size and h' is image size

Extrafocal Distances

Provides us with the relationship between object and primary focal point and image and secondary focal point.



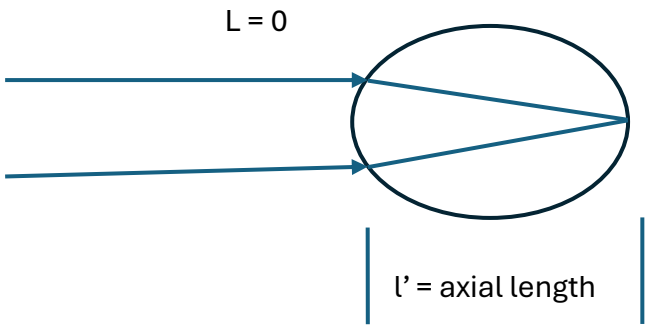
x = object Extrafocal distance

x' = image Extrafocal distance

Correcting Refractive Errors

Schematic Eye Model

Simplified Model



Emmetropic Eye

For distant object (optical infinity):
Incident Vergence = 0 (parallel incident rays)
Therefore, l' is the length of the eye (axial length)
L' = 1.33 / l' (index of aqueous and vitreous is 1.33)
F of the eye must be 1.33 / axial length

The power $F_{correction}$ to "correct" the eye is L' – $F_{eye\ power.}$

Far Point (PR)

The farthest point which gives a clear retinal image
The point conjugate to the retina with accommodation relaxed

Far Point for Myopia is between the eye and infinity
Far Point for Hyperopia is behind the eye

Myope has too much plus power
Hyperope has too little plus power

Refractive Error & Far point

RE = 1 / Far point (meters)

An object at infinity forms an image in the secondary focal plane of the eye for emmetrope.
For myope or hyperope, the image is formed in the secondary focal plane of the correcting lens.

The secondary focal point of the correcting lens is the far point of the eye.

There is a difference between the power of the spectacle lens (which usually is about 13mm in front of the cornea) and the power of a contact lens (which sits on the cornea).

For a myope, the spectacle lens is higher power than the contact lens power.
For a hyperope, the spectacle lens is lower power than the contact lens.

The optical principle here is known as effectivity.

In theory, if we know the axial length and the power of the eye, we can determine the refractive error.

Example: What eye power is needed for an eye with an axial length of 22mm to be emmetropic:

Remember: L + F = L'
L' is n'/l' where l' is the axial length (in meters) and n' is 1.33.
For an emmetrope L must be 0, since we want an object at infinity to create a clear retinal image.
F is the power of the eye.

F = L' – L
F = L' – 0
F = L'
F = 1.33/0.022m
F = +60.45

Example: What contact lens power is required to correct an eye with a power of +60.00 and an axial length of 24mm:

$F_{correction}$ = L' -I F_{eye}
Fc = 1.33/0.024 – 60.00
Fc = +55.00D – (+60.00D)
Fc = -5.00D

If a spectacle lens with a vertex distance (distance between lens and cornea) of 13mm is to be used for this eye what power of spectacle lens is required:

Remember, we want the secondary focal point of the lens to coincide with the far point.
The far point (in meters) is 1/refractive error. Therefore, far point is 0.20m in front of the eye.
Lens will be 13mm closer to far point than the eye (0.20 -0.013) = 0.187m.
The spectacle lens will be 18.7cm from the far point.
F' = n/f'
F' = 1.00/0.187
F' = -5.35D

Potential Exam Items

Concept Questions

What is the optic axis. (line through point source, horizontal line center of optical system)
What is the Chief Ray. (ray that passes through center of pencil of light)
What is meant by term Paraxial Region. (region very close to optical axis)
What are sign conventions for distances on optical axis. (left is negative, right is positive)
What are Incident Rays. (rays from object to lens element)
What are Emergent Rays. (rays from lens element to image)
What is Vergence / Power relationship. (L + F = L')
What is Positive / Negative Vergence. (Positive = Convergence / Negative = Divergence)
Where are Real / Virtual Objects located. (Real : Object Space / Virtual : Image Space)
Where are Real / Virtual Images located. (Real : Image Space / Virtual : Object Space)
What is a Single Refracting Surface. (a curved interface between two indices of refraction)
What is relationship between Radius and Surface Power. (greater radius : lower power)
What does spherometer measure. (sagittal depth)
What is the Primary Focal Length. (distance from surface to Primary Focal Point)
What is the Secondary Focal Length. (distance from surface to Secondary Focal Point)
What is the shape of a Positive Powered Surface. (convex if n' > n)
What is the shape of a Negative Powered Surface. (concave if n" > n)
What do you see when you look at the pupil of the eye (the image of the pupil)
What is the far point (point conjugate to retina or farthest point for clear image)
Where is the secondary focal point of a correcting lens (at the far point of uncorrected eye)
Compare Contact Lens and Spectacle Rx for myope (CL power is lower, opposite for hyperope)

Types of Problems (math oriented)

Determine vergence at any point in an optical system (object, lens element, and image).
Determine if image is real or virtual by calculating L' and l'.
Determine Incident and Emergent vergences for an optical system.
Use image and object distances to find power of lens element (F = L' - L).
Use Lens Power to find image location (l' = 1/L').
Find surface power of Single Refracting Surface (F = n'-n/r).
Find radius of curvature with approximate sag formula (r = y2/2s).
Find true power of a lens surface when n of lens in not equal to n of lens clock.
Use lens power and sagittal depth to find edge thickness of lens.
Find center thickness of lens.
Calculate reduced vergences.
Locate object or image given SRS surface power and index.
Determine image location, lateral magnification, and image type with SRS.
Determine Primary and Secondary Focal point locations for SRS.
Determine Primary and Secondary Focal lengths for SRS.
Determine Lateral Magnification for SRS.
Determine refractive error with eye power and axial length.
Find far point of ametropic eye.