



Al-Furat Al-Awsat Technical University
College of Health and Medical Technologies - Kufa
Department of Vision Screening Techniques

Second Stage 2025-2026

REFRACTIVE ERRORS 1

Lecture Title
Light

Lecture Number: 1 / course 1

Prepared by
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OPTOMETRIST

Light

1. Definition of Light

- Light is electromagnetic radiation detectable by the human eye.
- Visible range: ~400–700 nm (violet to red).
- Light behaves as both a wave characterized by wavelength (λ) and frequency ν ($\nu = \frac{c}{\lambda}$) and as particles (photons) carrying energy $E = h\nu$.

This duality explains key optical phenomena such as interference, diffraction, and the principle of lasers.

2. Measures of Light: Radiometry vs Photometry

- **Radiometry** (physical): radiant power (W), luminous intensity ($\frac{W}{sr}$), irradiance ($\frac{W}{m^2}$), radiance ($\frac{W}{sr \cdot m^2}$).
- **Photometry** (visual weighting, photopic $V(\lambda)$): luminous flux (lumen), luminous intensity (candela), illuminance (lux), luminance ($\frac{cd}{m^2}$).
- Conversions use the photopic luminosity function; scotopic/mesopic conditions use different weightings. These metrics are essential when specifying instrument brightness and safety.

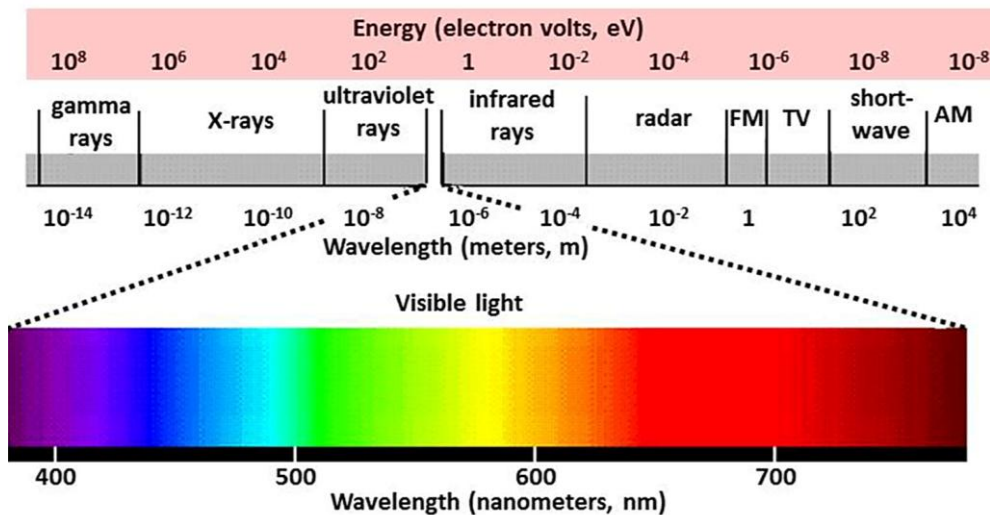
3. Electromagnetic Spectrum & Ocular Biophysics

Optical radiation lies between X-rays and microwaves and is commonly subdivided (approximate ranges):

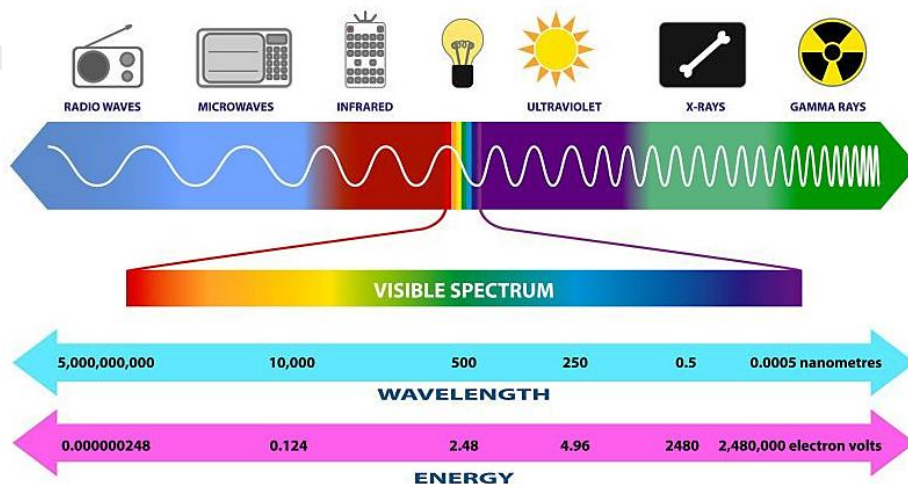
- UVC: 200–280 nm → absorbed by cornea/sclera; does not reach the lens/retina.
- UVB: 280–315 nm → largely absorbed by cornea; photokeratitis risk.

- UVA: 315–400 nm → absorbed by crystalline lens; chronic exposure implicated in lens changes.
- Visible: 400–780 nm → transmitted to retina; enables vision.
- IRA: 780–1400 nm → can reach retina; thermal injury risk at high intensities.
- IRB: 1400–3000 nm → absorbed by cornea/sclera.
- IRC: 3000–10,000 nm → absorbed by cornea/sclera.
- Rule: Shorter wavelength = higher energy.

Aphakic patients often report transient blue-tinged vision post-surgery because short wavelengths, previously filtered by the lens, now reach the retina; many modern IOLs incorporate UV-absorbing chromophores.



ELECTROMAGNETIC SPECTRUM



4. Speed of Light

Light propagates at a maximum speed in vacuum (c) and more slowly in materials. The extent of slowing and the degree to which light bends at an interface are quantified by the refractive index (n). Merging speed and refractive index emphasizes that 'speed' and 'refraction' are two aspects of the same concept.

- Speed in vacuum: $c \approx 3 \times 10^8$ m/s (constant).
- Refractive index definition: $n \equiv c / v$, where v is the phase velocity of light in the medium
- The speed of light changes when it passes through different media (like water or glass), slowing down as it enters denser materials.

Examples of refractive index are:

- Air = 1
- Water = 1.333
- Aqueous humour = 1.336
- Cornea = 1.376
- Crystalline lens = 1.386 – 1.406
- Crown glass = 1.52
- Flint glass = 1.62
- Diamond = 2.42

5. Interaction with Matter

- Reflection – light bounces back.
- Refraction – bending at media interfaces.
- Absorption – converted to heat/chemical energy.

- Transmission – passing through a medium.
- Scattering – light deviates in multiple directions.

Example: In aphakia, unfiltered UV reaches the retina → bluish vision.

6. Importance of Light

- Light is essential for vision, allowing us to see the world around us.
- It plays a crucial role in processes like photosynthesis, which is vital for life on Earth.
- Light is also used in various technologies, including communication, medicine, and energy.

7. Optical Medium

Light rays can travel through any transparent (clear) material. A transparent material that allows light to pass through it is called an optical medium.

An optical medium can be a:

- gas (like air)
- liquid (like water)
- solid (like glass or clear plastic)

8. Reflection

Angle of incidence equals angle of reflection; incident ray, reflected ray, and the normal lie in the same plane, such as a mirror.

Law of reflection: angle of incidence = angle of reflection

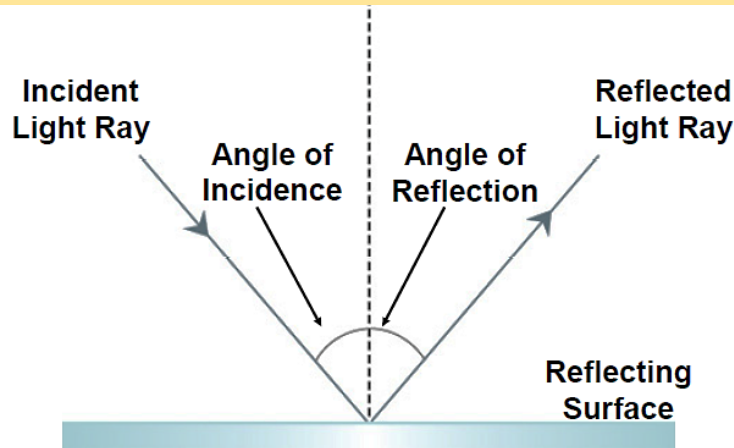


Figure: Reflection

9. Refraction

When a light ray travels from a medium with a lower refractive index into a medium with a higher refractive index, it is bent towards the normal.

According to the law of refraction:

$$n_1 \sin\theta_1 = n_2 \sin\theta_2$$

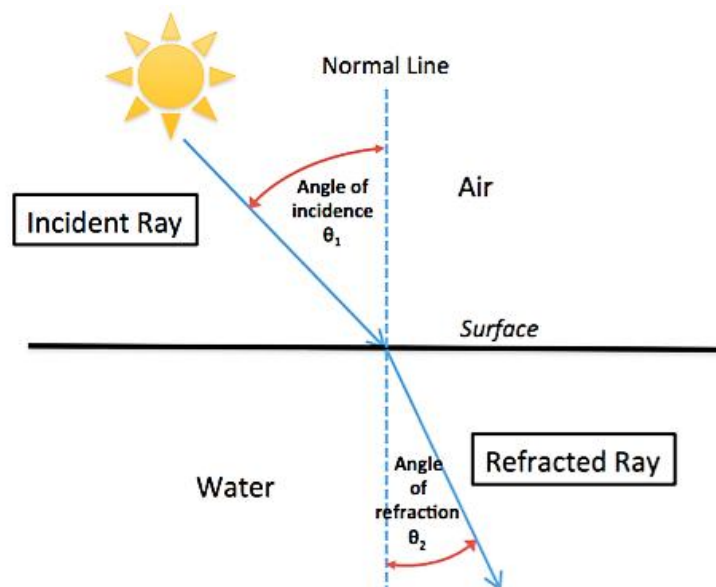


Figure: Refraction

When a light ray travels from a medium with a higher refractive index (high density) into a medium with a lower refractive index (low density), the light ray is bent away from the normal. "VICE VERSA"

10. Behaviour of Light

Light rays can travel in different directions or the same direction. Types of light rays include:

- **parallel light rays:** Light travels from an object into our eyes by moving in straight lines. These lines are called light rays.

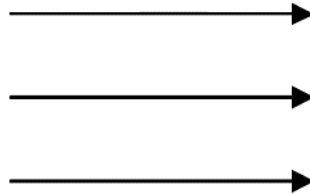


Figure 1: Parallel light rays

- **convergent light rays:** Convergent light rays will meet at a focal point.

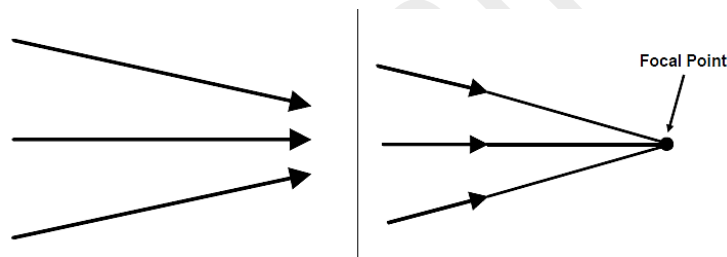


Figure 2: Convergent light rays converge to a focal point

- **divergent light rays:** Divergent light rays come from an object less than 6 m from the eye.

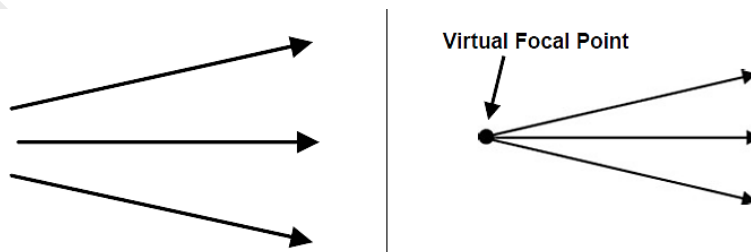


Figure 3: Divergent light rays

11. Ocular Media & Clinical Implications

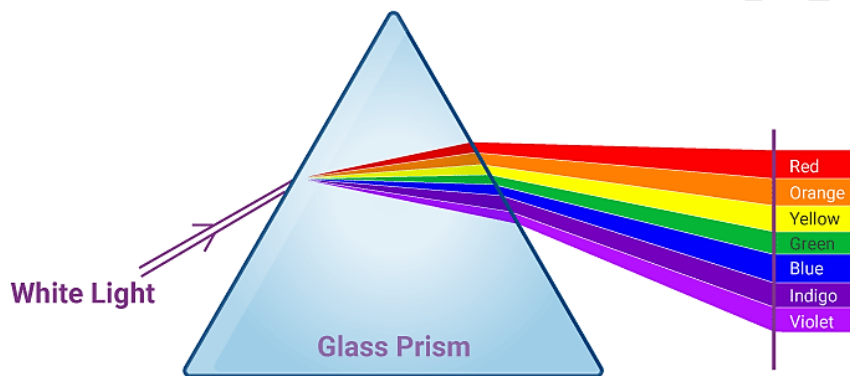
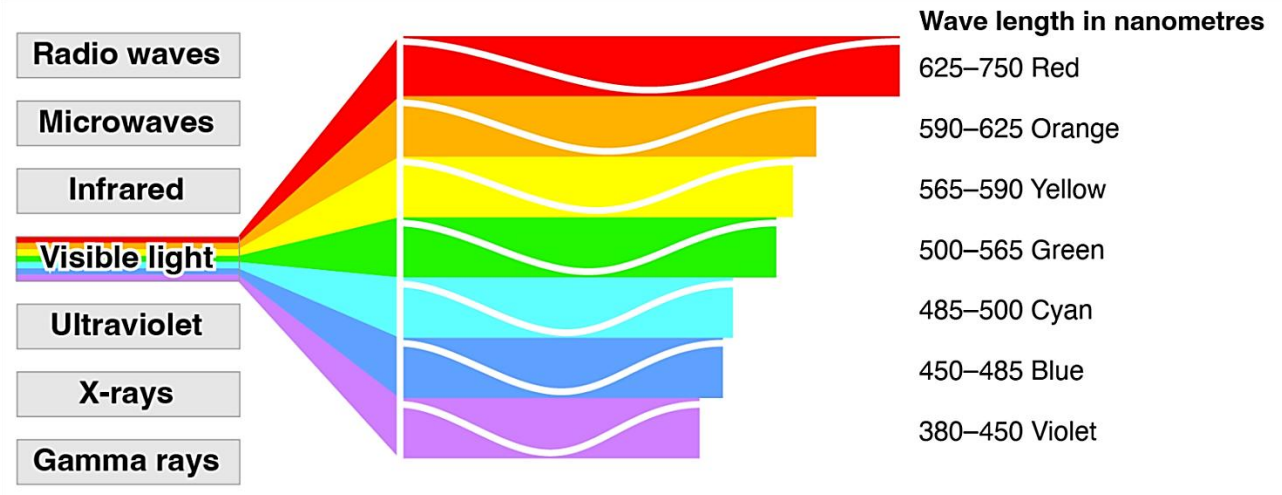
The cornea, aqueous humour, crystalline lens, and vitreous humour transmit and refract light. The cornea contributes approximately two-thirds of the eye's refractive power, and the lens provides variable power by accommodation. Age-related lens yellowing shifts transmission toward longer wavelengths, affecting color perception and glare.

12. Physical Optics

- Polarization: reduces glare; used in filters and some clinical tests.
- Coherence: exploited in OCT (low-coherence interferometry).
- Interference: thin-film colors of the tear film; fundamental to OCT ranging.
- Diffraction: explains blur with very small pupils (pinhole effect).
- Scattering: Rayleigh/Mie mechanisms affect retinal image quality and the appearance of the sky.

13. Visible Spectrum

- Human trichromacy arises from S-, M-, and L-cones. Congenital deficiencies include protanopia, deuteranopia, and tritanopia; acquired dyschromatopsia often accompanies retinal and optic nerve disorders.
- Common tests: Ishihara plates, Farnsworth D-15, FM 100-Hue under daylight-equivalent illumination.



14. Lasers & Light–Tissue Interaction

Ophthalmic lasers are monochromatic, coherent, and collimated. Interactions include photothermal (argon photocoagulation), photochemical (photodynamic therapy), and photodisruptive (Nd: YAG capsulotomy). Effects and safety depend on wavelength, pulse duration, spot size, and irradiance.

15. Light Hazards & Protection

Hazards include photochemical injury (blue–UV) and thermal damage (visible–IR-A at high irradiance). Instruments may include yellow/UV filters; control exposure duration and intensity. UV-blocking eyewear and UV-absorbing IOLs reduce the risk.

16. Clinical & Technological Importance

- Essential for vision.
- Key for diagnostics (slit lamp, fluorescein angiography, OCT).
- Basis for therapeutics (laser, photodynamic therapy).
- Broader uses: fiber-optic communication, solar energy, imaging

HOME WORK

1. Problem-Solving (Calculations)

- Compute the photon energy for $\lambda = 500 \text{ nm}$. Express in Joules.
- What is the speed of light in crown glass ($n = 1.52$)?
- A ray in air ($n_1 = 1.00$) enters the cornea ($n_2 = 1.376$) at 30° to the normal. Find the refracted angle.
- Compute the critical angle for total internal reflection from cornea ($n = 1.376$) to air ($n = 1.00$).
- A light ray travels from air into water. If the angle of incidence in the air is 30° , calculate the angle of refraction in the water.
- Consider a light ray traveling from crown glass to air. If the angle of incidence in the glass is 45° , calculate the angle of refraction in the air.

2. Reflection and Refraction (Essay)

Write a short essay (300-500 words) on how reflection and refraction of light are used in designing optical instruments, such as eyeglasses, cameras, or microscopes. Discuss the importance of understanding these concepts in the field of optometry.

3. Clinical Vignettes (Short Cases)

- A 68-year-old aphakic patient reports that everything looks 'bluer' after cataract extraction without IOL. Explain the physics and suggest a remedy.
- During gonioscopy, the anterior chamber angle becomes visible despite corneal total internal reflection. Why?



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Mirror & lens

Lecture Number: 2 / course 1

Prepared by
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Mirror & lens

Mirror: a smooth, highly reflective surface that typically reflects light to form an image of whatever is in front of it. Mirrors work by reflecting incoming light rays at the same angle at which they strike the surface, according to the law of reflection. The most common type of mirror is a plane mirror, which has a flat surface and reflects images in their true proportions, although they are reversed from left to right.

Types of mirrors and image properties

1. Plane mirror (flat): upright, virtual, same size; image distance behind the mirror equals object distance in front; lateral inversion occurs.

2. Spherical mirrors: Curved mirrors that can be either concave (converging) or convex (diverging).

✓ **Concave mirrors (converging)** can produce real (inverted) or virtual (upright) images depending on object position; they focus parallel rays to the focal point.

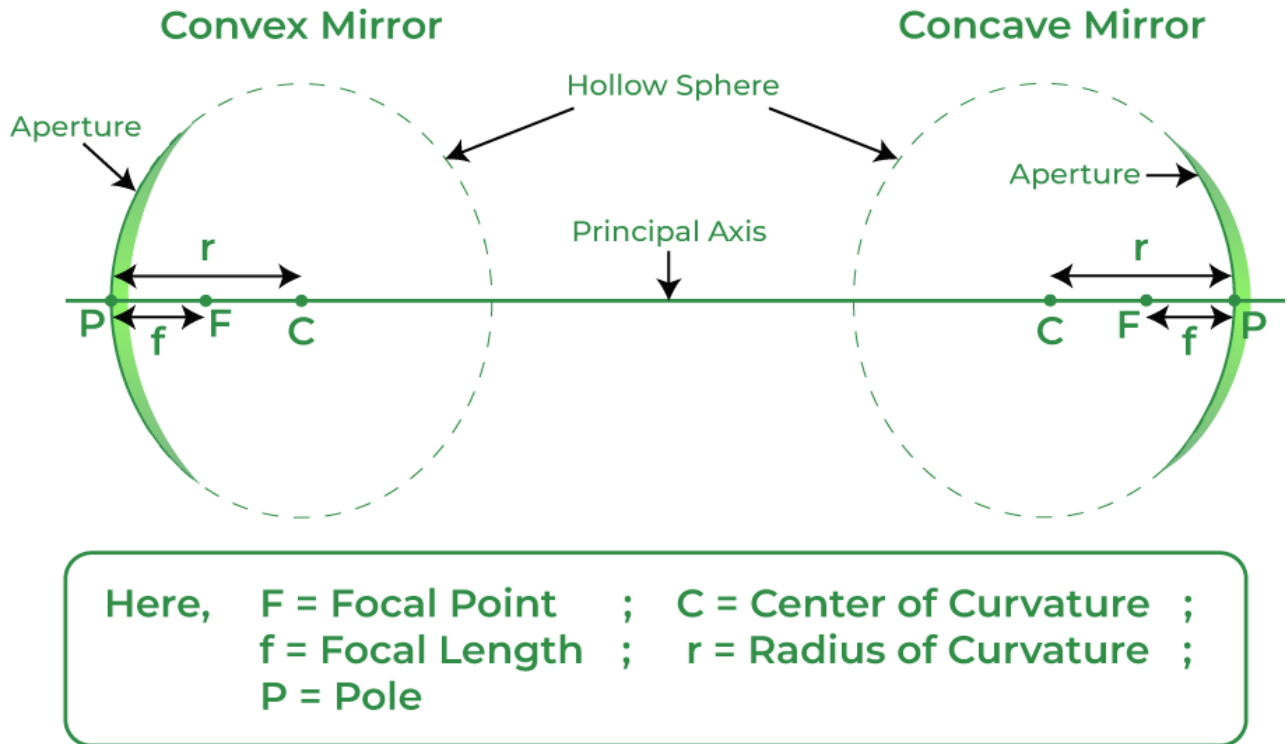
✓ **Convex mirrors (diverging)** always form virtual, upright, reduced images.

Governing relations for spherical mirrors:

- Focal length: $f = R/2$ (R = radius of curvature).
- Mirror (Gaussian) formula: $1/f = 1/d_o + 1/d_i$.
- Magnification: $m = -d_i/d_o$ (negative sign indicates inversion for real images).

Quick ray rules (concave mirror):

- Ray parallel to the principal axis reflects through the focal point (F).
- Ray through F reflects parallel to the axis.
- Ray through the center of curvature (C) retraces its path.

**Properties of Images Formed by Plane Mirrors**

- Image Type: Virtual (cannot be projected on a screen).
- Image Orientation: Upright.
- Image Size: The same size as the object.
- Image Distance: The image appears to be the same distance behind the mirror as the object is in front of it.
- Lateral Inversion: The image is laterally inverted, meaning left and right are reversed.

Lenses: An optical lens (or simply a lens) is a piece of transparent material that is shaped to refract light rays, focusing them at a specific point, known as the focal point.

Lenses are used for spectacles, magnifying glasses, microscopes, and slide projectors. Spectacle lenses can change the focus of the eyes, making sight clearer.

If an eye has a refractive error (like hyperopia, myopia, astigmatism or presbyopia), a spectacle lens can be used to correctly focus the light coming into the eye so that the vision becomes clear.

Lenses are typically made of glass or plastic and come in various shapes. The most common lens shapes are:

- ❖ **Spherical:** plus and minus lenses
- ❖ **Astigmatic:** cylindrical and spherocylindrical lenses

A lens will bend light rays by different amounts depending on the refractive index of the lens material and the point on the lens surface where the incident light ray enters.

Plus Lens: also known as a convex lens or converging lens, is a type of lens that is thicker at the center than at the edges. It is called a "plus" lens because it has a positive focal length, meaning it converges parallel light rays to a single point known as the focal point.

Minus Lens: also known as a concave lens or diverging lens, is a type of lens that is thinner at the center and thicker at the edges. It is called a "minus" lens because it has a negative focal length, meaning it diverges parallel light rays away from a point known as the focal point.

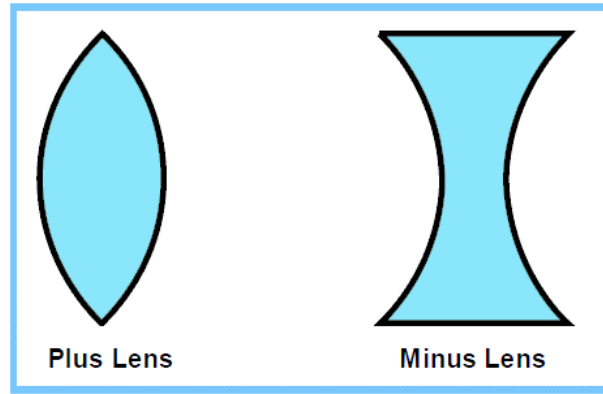
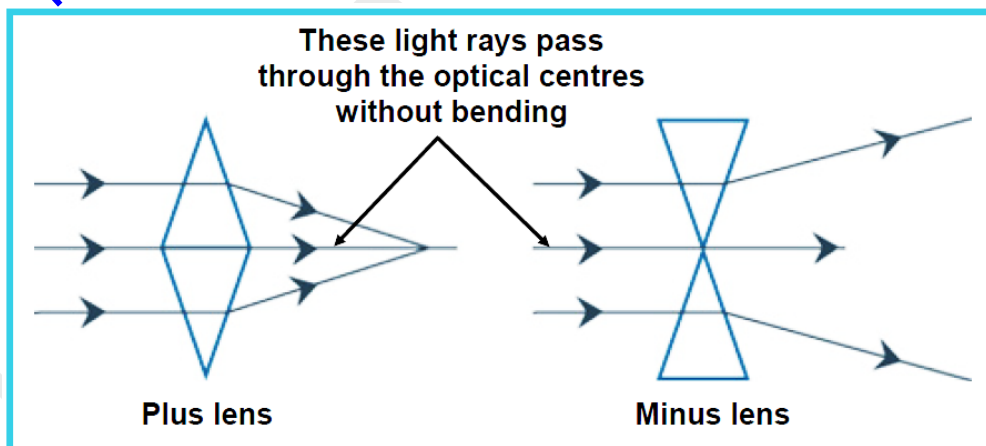


Figure 1: Plus and minus lenses

Optical Centre (OC): A light ray will not be refracted or bent if it travels through the optical center of a lens.

A plus lens can be thought of as two prisms that are joined base to base.
A minus lens can be thought of as two prisms that are joined apex to apex.



- Thin-lens (Gaussian) formula: $1/f = 1/d_o + 1/d_i$.
- Lens power: $P = 1/f$ (meters) in diopters (D).

Astigmatic lenses

Astigmatic lenses correct different powers in two principal meridians (usually orthogonal).

- Cylindrical lens: adds power only in the meridian perpendicular to its axis; the axis meridian has zero cylinder power.
- Spherocylindrical lens: sphere (affects all meridians equally) + cylinder (adds power in one meridian).
- Prescription: Sphere / Cylinder × Axis. Axis is the meridian of zero cylinder power.
- Transposition (plus ↔ minus cyl): new sphere = old sphere + cylinder; change sign of cylinder; rotate axis by 90°.
- Regular astigmatism forms two line foci (interval of Sturm) rather than a point focus.

Types of Astigmatic Lenses

- **Cylindrical Lenses:** have different curvatures in different meridians (directions) of the lens, which allows them to focus light along one axis more than the other. These lenses correct astigmatism by compensating for the uneven curvature of the cornea or lens.

The prescription will typically have three components: spherical power is zero, cylindrical power, and axis.

$$0.00 / \pm 1.00 \times 90^{\circ}$$

- **Spherocylindrical Lenses:** combine both spherical and cylindrical components in one lens. The spherical component corrects nearsightedness (myopia) or farsightedness (hyperopia), while the cylindrical component corrects astigmatism.

The prescription will typically have three components: spherical power, cylindrical power, and axis.

$$\pm 0.50 / \pm 1.00 \times 90^\circ$$

Sign Conventions

- Be consistent with the chosen sign convention for distances.
- Real images: rays actually converge; virtual images: apparent intersection only.
- Magnification sign: negative = inverted; positive = upright.
- Cylinder power acts 90° to the axis (not along the axis).

HOME WORK

Short-Answer Questions

1. State the three quick ray rules for a concave mirror.
2. Give two properties of images in a plane mirror.
3. Define lens power and its unit.
4. What does “axis” mean in a cylinder prescription?
5. State the thin-lens (Gaussian) formula.

Calculation Problems

1. Concave mirror: $f = +20$ cm, object at $d_o = 60$ cm. Find d_i and m .
2. Convex mirror: $f = -15$ cm, object at $d_o = 40$ cm. Find d_i and m .

Clinical/Practical Mini-Vignettes

- 1) Decentration & prism: A $+5.00$ D lens is decentered 4 mm nasally relative to PD. Compute induced prism and base direction (Prentice's rule).
- 2) Cylinder transposition: Transpose $+1.00 / -2.00 \times 180^\circ$ to plus-cyl form.



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REFRACTIVE ERRORS 1

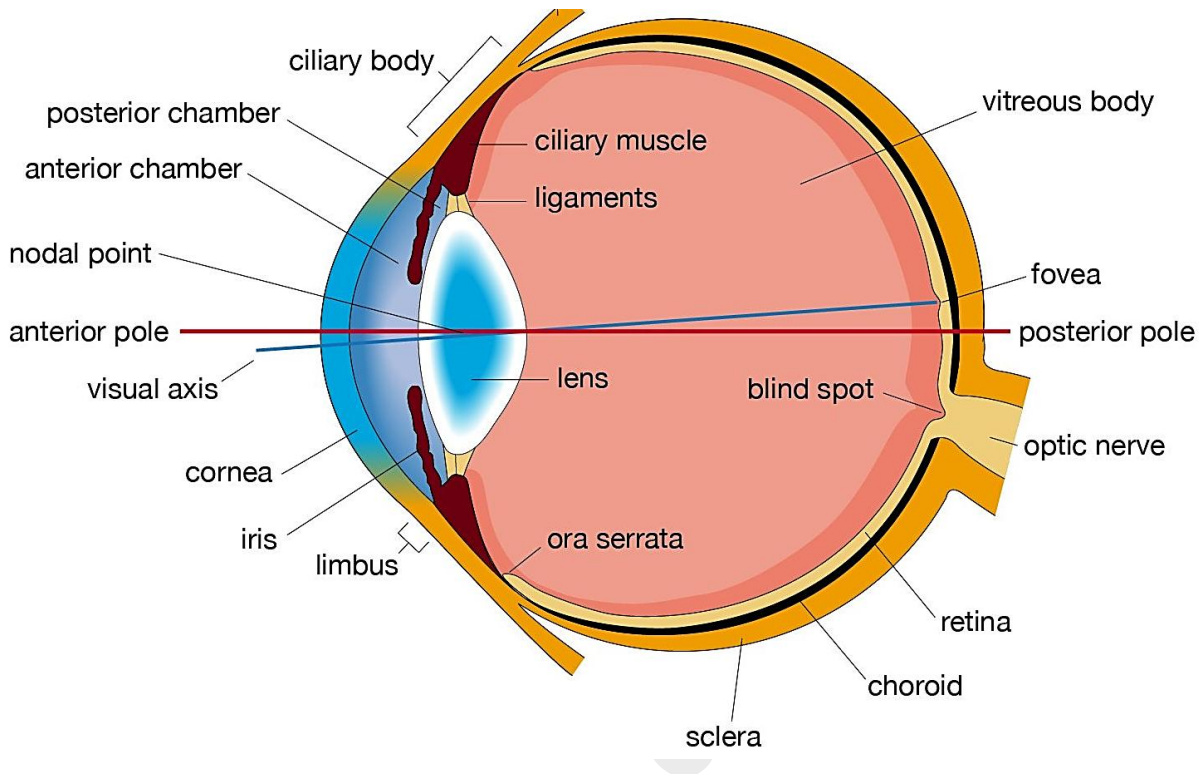
Lecture Title
Human Eye

Lecture Number: 3 / course 1

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Human Eye

Anatomy of the Eye



- **Cornea:** The transparent front surface of the eye that refracts light entering the eye.

- ✓ The cornea has a refractive index of approximately 1.376.
- ✓ The corneal power is approximately +43 diopters (D) in range (+40 to +45D)

- **Lens:** A flexible, transparent structure that further focuses light onto the retina. The lens can change shape to adjust focus, a process known as accommodation.

- ✓ The central part (nucleus) has a refractive index of approximately 1.406.
- ✓ The outer part (cortex) has a refractive index of approximately 1.386.
- ✓ The lens typically has a refractive power of around +18 to +20 diopters (D) in its relaxed state.

- **Iris and Pupil:** The iris controls the size of the pupil, which regulates the amount of light entering the eye.
- **Aqueous Humor:** is a clear, watery fluid found in the anterior segment of the eye. It fills the space between the cornea and the lens, including the anterior chamber (between the cornea and iris) and the posterior chamber (between the iris and lens). The aqueous humor has a refractive index of approximately 1.336.
- **Vitreous Humor:** is a clear, gel-like substance that fills the large vitreous chamber, which occupies the space between the lens and the retina. The aqueous humor has a refractive index of approximately 1.336
- **Retina:** The light-sensitive layer at the back of the eye, where light is focused and converted into electrical signals sent to the brain.
- **Optic Nerve:** Transmits visual information from the retina to the brain.

Basic Optical Principles

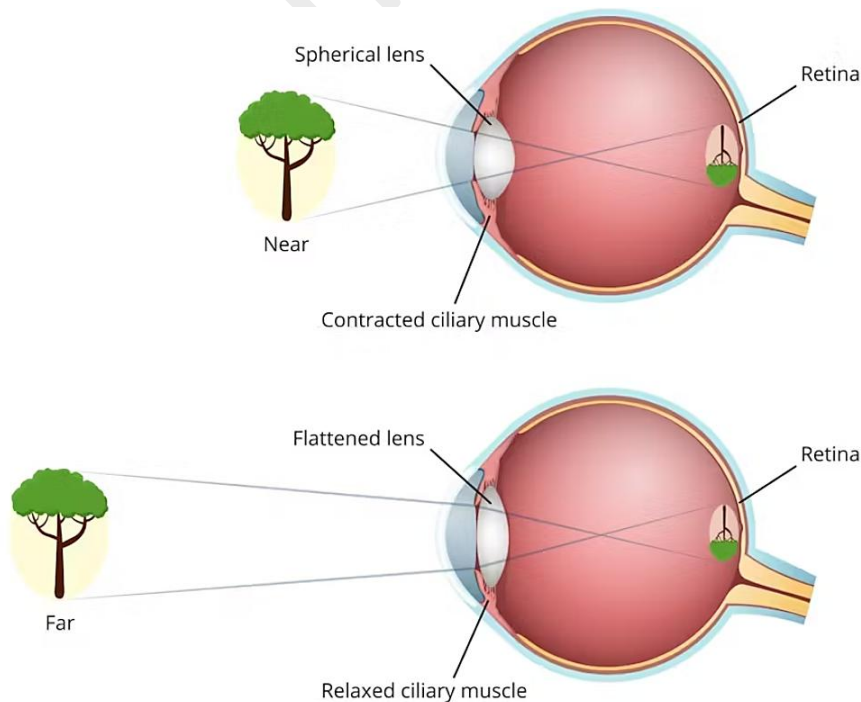
- **Refraction:** The bending of light as it passes through different media (air, cornea, lens) in the eye. This bending is crucial for focusing light on the retina.
- **Focal Point:** Light rays entering the eye are refracted and brought to a focal point on the retina. A sharp image is formed when light rays converge precisely on the retina.
- **Accommodation:** The eye's ability to focus on objects at varying distances by changing the shape of the lens. For near objects, the lens becomes thicker to increase its refractive power, while for distant objects, it flattens out.
- **Field of Vision:** The range of vision seen without moving the eyes. Peripheral vision is less sharp than central vision due to the distribution of photoreceptors on the retina.

Refractive Errors

- **Myopia (Nearsightedness):** Occurs when light rays focus in front of the retina, usually due to an elongated eyeball or overly curved cornea. Distant objects appear blurry.
- **Hyperopia (Farsightedness):** This happens when light rays focus behind the retina, often due to a shorter eyeball or flatter cornea. Close objects are blurry.
- **Astigmatism:** Caused by an irregularly shaped cornea or lens, leading to multiple focal points. Vision can be blurry or distorted at all distances.
- **Presbyopia:** Age-related loss of accommodation, making it difficult to focus on near objects as the lens loses flexibility.

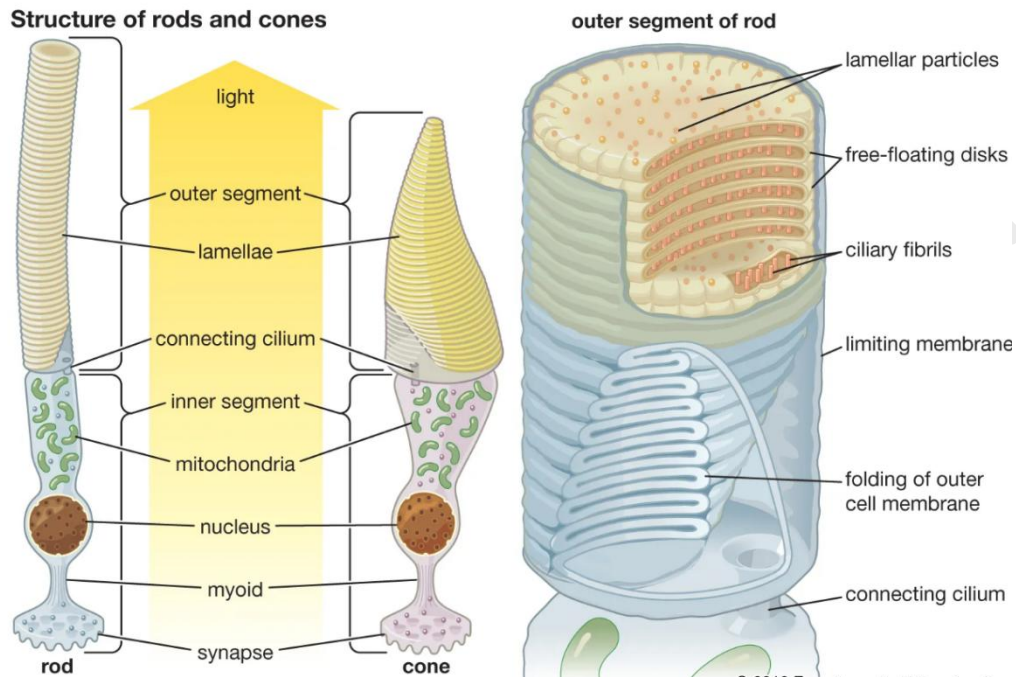
Image Formation

- **Inverted Image:** The image formed on the retina is inverted (upside-down). The brain processes this image and flips it so we perceive it correctly.
- **Resolution:** The sharpness of vision depends on the density of photoreceptor cells in the retina, particularly in the macula (the central part of the retina).

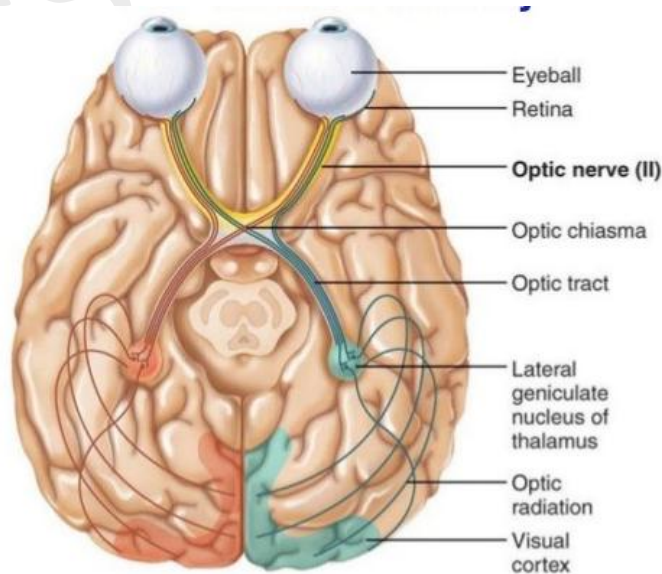


Photoreception

- **Rods and Cones:** The retina contains photoreceptor cells, rods (for low-light vision) and cones (for color and detail). Cones are concentrated in the fovea, a small pit in the macula, providing sharp central vision.

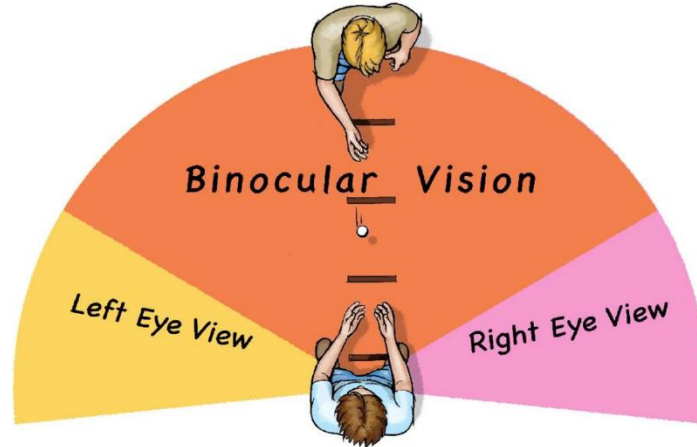


- **Visual Pathway:** Once light is converted into electrical signals by photoreceptors, these signals travel through the optic nerve to the brain's visual cortex, where they are processed into images.



Visual Perception

- **Binocular Vision**: The overlap of the visual fields of both eyes provides depth perception and a 3D view of the world.



- **Stereopsis**: The brain compares slightly different images from each eye to perceive depth, a phenomenon known as stereopsis.

Schematic Eyes

Gullstrand's Schematic Eye

Gullstrand's Schematic Eye is a more detailed and anatomically accurate model of the human eye, developed by the Swedish ophthalmologist Allvar Gullstrand.

- It includes multiple refracting surfaces and has six refracting surfaces.

Refractive Components:

- Anterior cornea
- Posterior cornea
- Anterior lens
- Posterior lens
- Aqueous and vitreous humors
- The accommodation exerted in the accommodative state is 10.6D.
- The power of the cornea is +37.7D, and the power of the lens is +19.11D.

- Total Refractive Power: +58.64 D, so it has a refractive error of +1.00 D (hypermetropic)

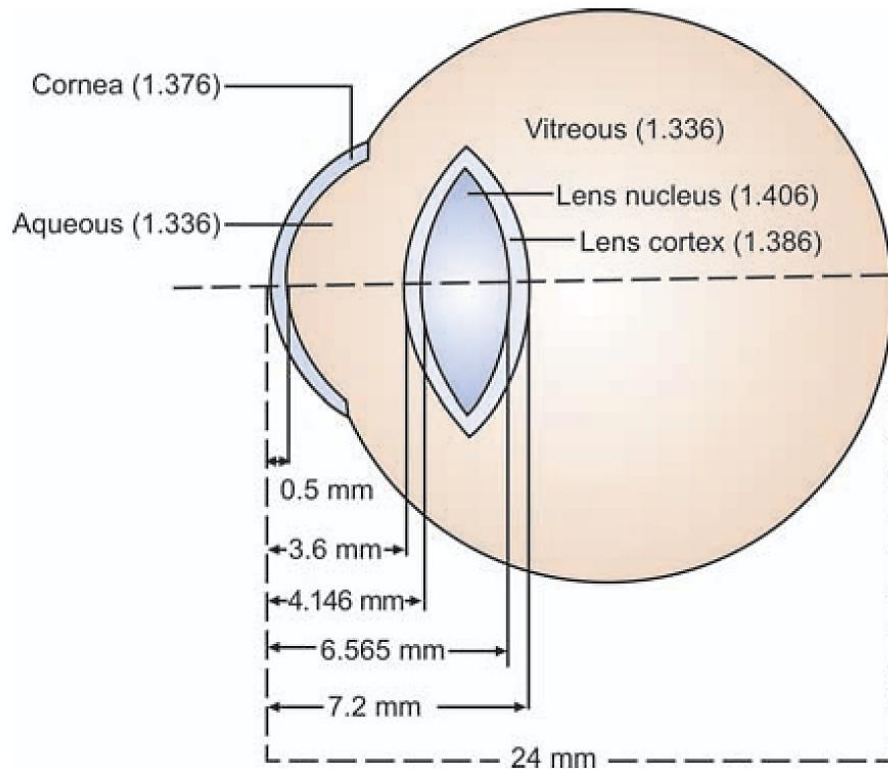


Figure: Gullstrand's Schematic Eyes

Gullstrand–Emsley schematic eye

Harold Emsley was a British optician and optical scientist known for his contributions to the field of physiological optics, particularly in the study and modeling of the human eye. His work is highly regarded in the field of vision science and optical design.

“Emsley developed this schematic eye with modifications of Gullstrand's schematic eye”.

- The lens is made optically homogeneous, i.e., the central nuclear area having a different refractive index is abolished.
- The posterior corneal surface is also removed.
- It has three refracting surfaces.
- The refractive index of aqueous humour and vitreous humour is 1.333.
- Total Refractive Power: +60.00 D, so is emmetropic

- First focal point (f_1) = – 16.67 mm in front of the cornea
- Second focal point (f_2) = + 22.22 mm behind the cornea
- The axial length of this reduced eye = +22.22 mm
- The radius of curvature of the cornea = 5.55 mm.

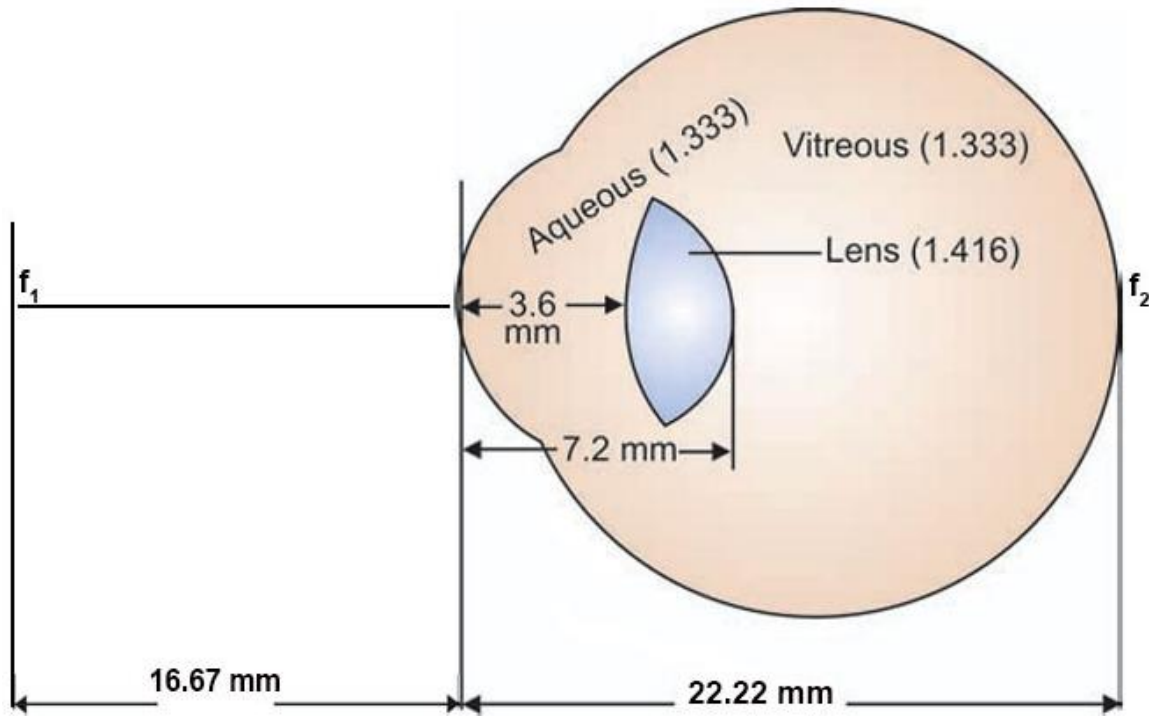


Figure: Gullstrand–Emsley schematic eye

Donder's Reduced Eye

is a simplified model of the human eye, introduced by the Dutch ophthalmologist Franciscus Cornelis Donders in the 19th century. This model is used to help understand the basic optical principles of the eye more straightforwardly.

- It has only one refracting surface, i.e., the cornea, with the elimination of the lens.
- Its total dioptric strength is +58.6D, and its refractive index is 1.336.
- It is emmetropic with a second focal length, i.e., axial length of 24.13 mm, with the second focal point on the retina. The first focal point is 15.7 mm in front of the cornea.

- The radius of curvature of the cornea is 5.73 mm, as opposed to 7.7 mm in a schematic eye.
- Since there is only one refracting surface, the first and second principal planes, points and nodal points merge to form only one principal plane, principal point and nodal point.
- The principal point is 1.35 mm behind the anterior corneal surface and the nodal point is 7.08 mm behind the anterior corneal surface.

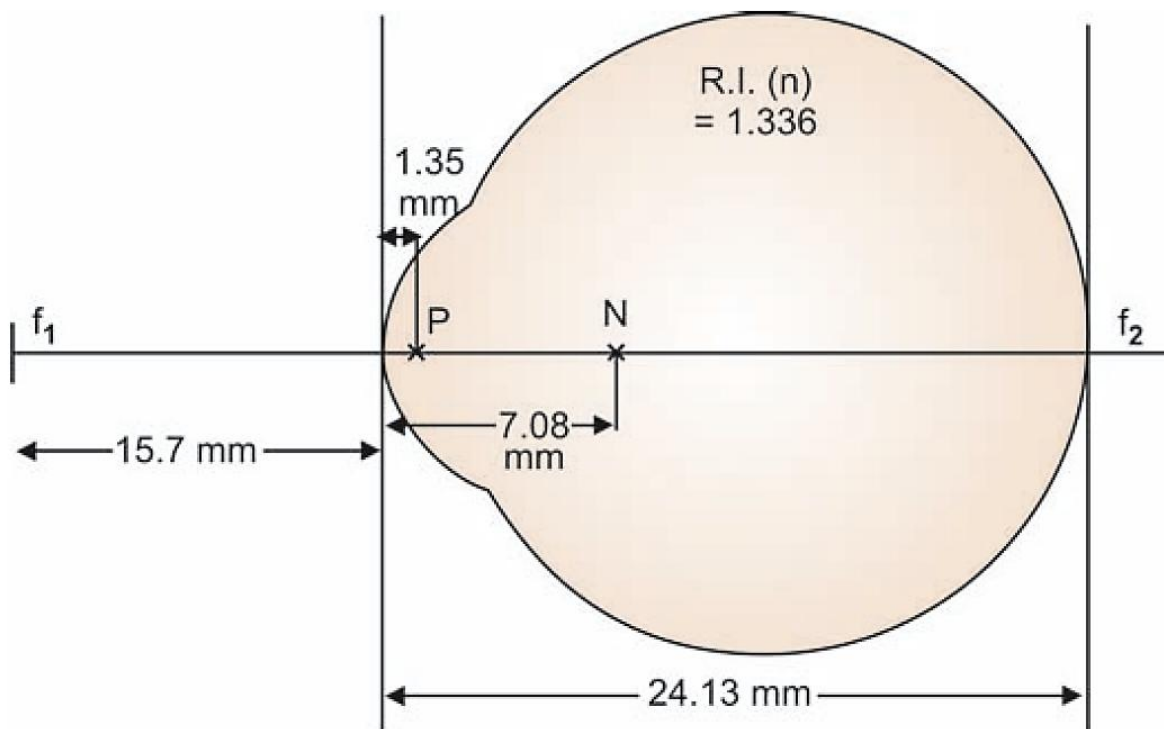


Figure: Donder's reduced eye. P = Principal point; N = Nodal point; f_1 = First focal point; f_2 = Second focal point

Axes of The Eye

Visual Axis: is the line that connects the object of regard (the point you're looking at), the center of the entrance pupil, and the fovea (the part of the retina responsible for sharp central vision) (F).

Optical Axis: is the line that passes through the centers of curvature of the cornea and lens. It represents the geometric center of the eye's optical system.

Pupillary Axis: is the straight line that passes through the center of the pupil (E).

Fixation Axis: is the line joining the fixation point with the center of rotation of the eyeball (C).

Angles of The Eye

Angle Alpha (α): is the angle between the optical axis and the visual axis.

Angle Kappa (κ): is the angle between the pupillary axis and the visual axis. This angle is particularly relevant in clinical assessments, such as in the measurement of strabismus. A large Angle Kappa can result in pseudo-strabismus, where the eyes appear misaligned due to the displacement of the visual axis.

Angle Lambda (λ): is often used interchangeably with Angle Kappa, though some distinctions are made in certain contexts. It refers to the angle between the pupillary axis and the line of sight. Angle Lambda is crucial in aligning optical devices, such as during laser eye surgery, to ensure the correction is centered on the visual axis.

Angle Gamma (γ): is the angle between the optical axis and the fixation axis.

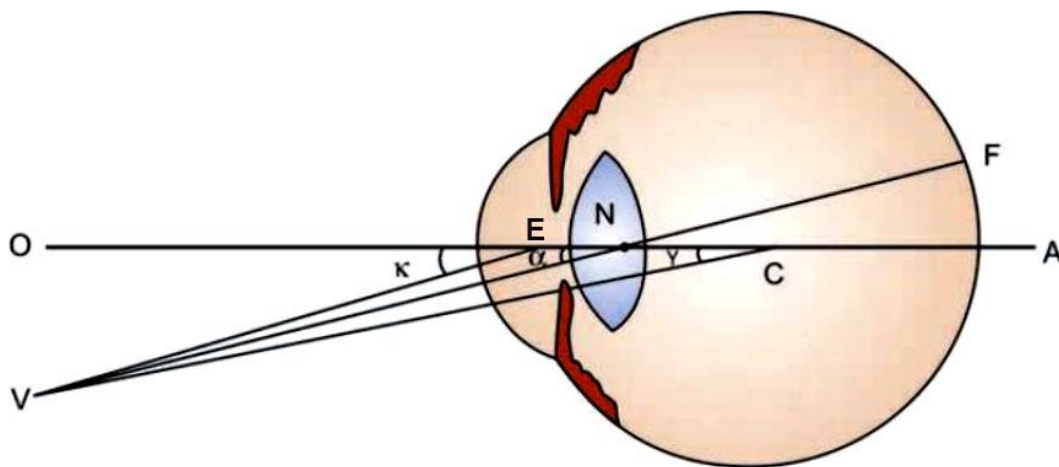


Figure: Axes and angles of the eye. OA = Optical axis; VF = Visual axis ; VC = Fixation axis ; VE = Pupillary Axis ; α = VNO ; κ = VEO ; γ = VCO and N = Nodal point

HOME WORK

1. **Explain how the cornea and lens work together to focus light on the retina.**
In your answer, mention their refractive indices and relative optical powers.
2. **Describe how accommodation occurs in the eye.**
What structural and refractive changes take place in the crystalline lens during near and distant focus?
3. **Differentiate between myopia, hyperopia, and astigmatism** in terms of where the image is formed and what structural changes cause each error.
4. **Define presbyopia** and explain the physiological reason it develops with age.
5. **Explain the difference between binocular vision and stereopsis.**
Why is stereopsis considered a higher level of binocular processing?
6. **Discuss the role of the retina and photoreceptors (rods and cones)** in image formation and color vision. How does their distribution affect visual resolution?
7. **Compare the optical and visual axes of the eye.**
Then define **Angle Kappa (κ)** and describe its clinical importance.
8. **Explain how the Gullstrand and Emsley schematic eyes differ** in structure and optical power. Why might an optometrist use a simplified model like Emsley's in calculations?
9. **Describe how the image formed on the retina is inverted,** and how the brain processes this image to produce correct visual perception.
10. **A patient after cataract extraction reports that everything appears bluish.**
Use your knowledge of ocular optics to explain why this happens and how it can be corrected.



Al-Furat Al-Awsat Technical University
College of Health and Medical Technologies - Kufa
Department of Vision Screening Techniques

Second Stage 2025-2026

REFRACTIVE ERRORS 1

Lecture Title
Refractive Error

Lecture Number: 4 / course 1

Prepared by
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OPTOMETRIST

Refractive Error

Introduction

Refractive errors are the most common visual disorders worldwide and one of the leading causes of correctable visual impairment. They occur when the eye fails to properly focus light on the retina, leading to blurred or distorted vision. A person with a refractive error needs spectacles (glasses) or contact lenses to achieve clear and comfortable vision. This occurs because the shape or size of the eye does not allow light to focus precisely on the retina.

Suppose light rays from distant or near objects do not converge properly on the retina. In that case, the person experiences visual blur due to a refractive mismatch between the optical system and the eyeball length.

There are four main types of refractive errors:

1. Myopia (Nearsightedness)
2. Hyperopia (Farsightedness)
3. Astigmatism
4. Presbyopia

Determinants of Refractive Status

The amount and type of refractive error in an eye depend on three main anatomical and optical factors:

- **The curvature of the cornea:** Steeper curvature increases refractive power (common in myopia), while a flatter cornea decreases it (common in hyperopia).
- **The thickness and refractive index of the crystalline lens:** A thicker lens with higher curvature increases focusing power; age-related changes in lens elasticity affect accommodation and may lead to presbyopia.
- **The axial length of the eyeball:** A longer eyeball focuses light in front of the retina (myopia), while a shorter eyeball focuses light behind it (hyperopia).

Optical Components and Their Roles

- The cornea and crystalline lens are the main refractive structures of the eye.
- The cornea provides approximately two-thirds (≈ 43 diopters) of the total refractive power.
- The lens contributes about one-third (≈ 17 diopters) and fine-tunes the focus for near and far vision (accommodation).

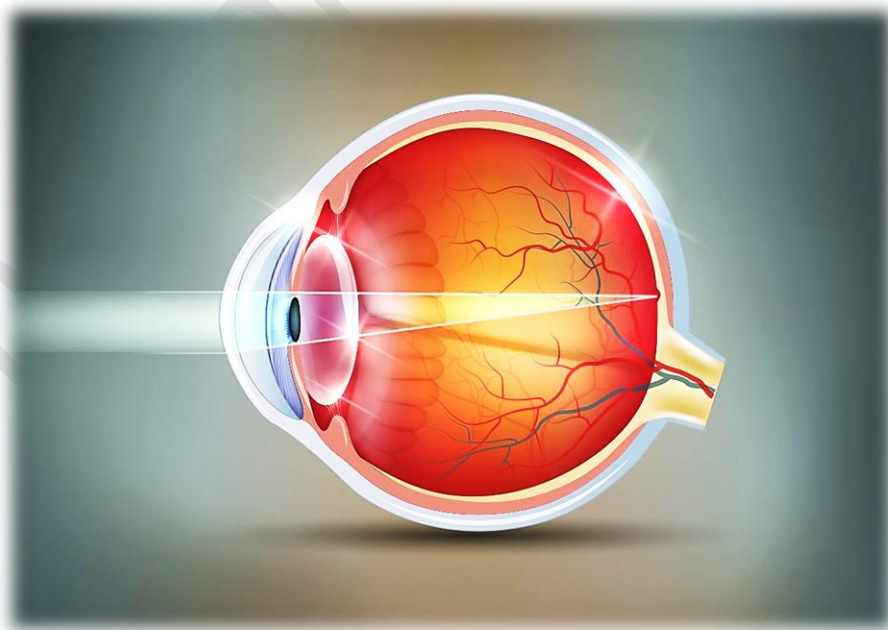
Any imbalance between these two components and the axial length of the eye results in a refractive error.

Refractive Power and Diopters

Refractive power is measured in diopters (D), representing the ability of the eye to bend light. An emmetropic eye typically has a total refractive power of around +60 D, focusing parallel light rays from infinity directly onto the retina.

The Normal Eye (Emmetropia)

Emmetropia is the ideal optical state of the human eye in which light rays focus precisely on the retina, producing clear vision at all distances without corrective lenses.



Key Characteristics of Emmetropia:**1. Normal Eye Shape:**

- The eyeball's axial length (23.0–24.5 mm) is proportionate to its optical power.
- The cornea and lens curvature work harmoniously to direct light precisely onto the retinal surface.

2. Perfect Focus:

- Light rays entering the eye are bent (refracted) by the cornea and lens so that they converge exactly on the retina.
- The retina, located at the back of the eye, acts like a screen that captures the focused image and sends it to the brain via the optic nerve for interpretation.

3. Clear Vision at All Distances:

- An emmetropic eye sees both near and distant objects clearly without additional focusing effort.
- No optical correction (glasses or contact lenses) is needed.

4. How Emmetropia is Determined:

- **Eye Examination:** No refractive errors detected.
- **Visual Acuity Test:** Vision reaches 20/20 (6/6) level.
- **Refraction Assessment:** No optical correction required for either distance or near vision.

5. Importance of Emmetropia:

- **Optimal Visual Function:** Emmetropia represents the best possible refractive balance, providing sharp and comfortable vision without eye strain.
- **Clinical Baseline:** It serves as a reference point for diagnosing and grading refractive errors. Any deviation from emmetropia indicates myopia, hyperopia, astigmatism, or presbyopia.

- **Eye Health Indicator:** Stable emmetropia reflects proper eye growth and balanced optical development.

6. Emmetropia Across Life Stages:

- **Infancy and Childhood:** Most newborns are mildly hyperopic (farsighted). As the eyeball grows, its length increases and often reaches emmetropia by late childhood, a process known as emmetropization.
- **Adulthood:** Emmetropia is most stable in young adults. The balance between corneal curvature, lens power, and axial length remains steady.
- **Middle Age and Beyond:** With aging, the crystalline lens loses elasticity, leading to presbyopia, an age-related refractive change that makes near vision difficult, even in previously emmetropic individuals.

Clinical Note

During a routine eye examination, assessing the refractive status of the eye is one of the most fundamental diagnostic steps in optometry and ophthalmology. The goal is to determine whether the light entering the eye is focused on, in front of, or behind the retina.

Clinical Evaluation Procedures:

- 1. Visual Acuity Test (Snellen Chart):** Measures the sharpness of vision at a standardized distance (usually 6 meters or 20 feet). 20/20 (6/6) vision indicates emmetropia, while reduced acuity suggests refractive error or ocular pathology.
- 2. Objective Refraction (Retinoscopy / Autorefraction):** Determines refractive power without patient input. Retinoscopy allows observation of retinal reflex motion; autorefractors provide computerized estimates.
- 3. Subjective Refraction (Phoropter Testing):** Fine-tunes the optical prescription by asking which lenses provide the clearest vision, confirming the corrective power needed.
- 4. Binocular Balance Test:** Ensures both eyes work together harmoniously, providing coordinated binocular vision.

Interpretation of Findings:

- If visual acuity = 20/20 (6/6) and retinoscopy shows no refractive deviation → the eye is emmetropic.
- If light focuses in front of the retina → myopia (nearsightedness).
- If light focuses behind the retina → hyperopia (farsightedness).
- If light focuses unevenly with multiple focal points → astigmatism.
- If near focus is lost due to aging lens changes → presbyopia.

Clinical Relevance:

- Early detection prevents visual strain, headaches, amblyopia (lazy eye), and academic issues in children.
- In children/adolescents: Regular screening identifies early-onset myopia (linked to near work and screen time).
- In adults: Maintaining emmetropia supports optimal vision for work and daily tasks.
- In elderly patients: Monitoring refractive status aids in managing presbyopia and lens changes.

Optometrist's Role:

- Evaluate refractive errors accurately.
- Prescribe glasses or contact lenses.
- Educate patients on visual hygiene and preventive measures (e.g., screen breaks, outdoor time for children).
- Coordinate with ophthalmologists for surgical correction (e.g., LASIK, PRK).

HOME WORK

Short Answer Questions

1. Define emmetropia in your own words.
2. List the three main factors that determine the refractive condition of the eye.
3. Explain why most children are slightly hyperopic and how this changes with growth.
4. Describe how an eye examination can determine whether a person has emmetropia.
5. What happens to near vision as a person enters middle age, even if they were previously emmetropic?

Applied / Clinical Thinking

1. A 20-year-old student reports difficulty seeing the board clearly but can read comfortably at close range.
 - What is the most likely refractive status?
 - How does this differ from emmetropia in terms of light focus?
2. During an eye exam, a patient has 20/20 vision and no corrective lenses are required.
 - What does this indicate about the optical alignment of their eye?
3. Explain why emmetropia is considered the **baseline reference** in refractive assessment.



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Second Stage 2025-2026

REFRACTIVE ERRORS 1

Lecture Title
Myopia

Lecture Number: 5 / course 1

Prepared by
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MYOPIA

Definition of Myopia: Myopia (shortsightedness or nearsightedness) is a refractive error in which distant objects appear blurry because light rays focus in front of the retina instead of directly on it. Myopic eyes often have an excessive axial length or too much refractive power, causing this focal point mismatch.

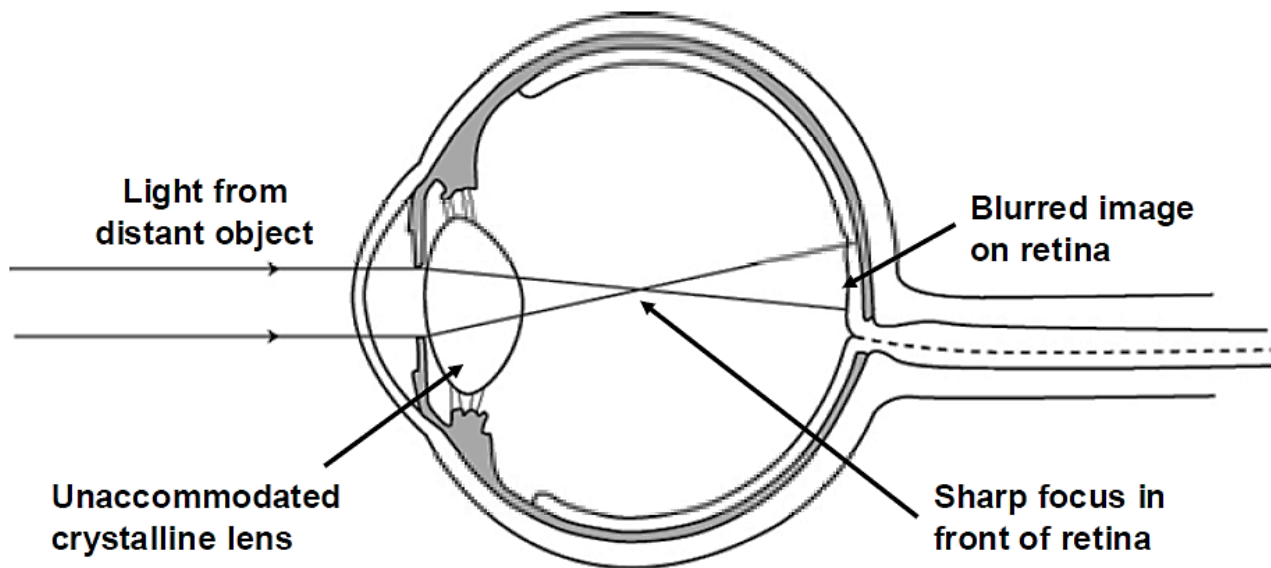


Figure: A myopic eye - light rays from a distant object focus in front of the retina

Epidemiology and Global Trends

- **Globally**, myopia has become one of the most common visual disorders, often described as a “**global myopia epidemic**.”
- In the year **2000**, about **23%** of the world’s population was myopic; by **2020**, the number increased to **34%**.
- If this trend continues, it is expected that by **2050**, around **50% of the global population**, nearly **5 billion people**, will be myopic, with about **10%** suffering from **high myopia (≥ -6.00 D)**, which carries serious risks of visual impairment.

- The rise is particularly pronounced among **children and adolescents**, especially in **urban environments** with high educational demands and reduced outdoor exposure.
- **East and Southeast Asia** currently report the highest rates worldwide, with up to **80–90% of teenagers** affected in some cities.

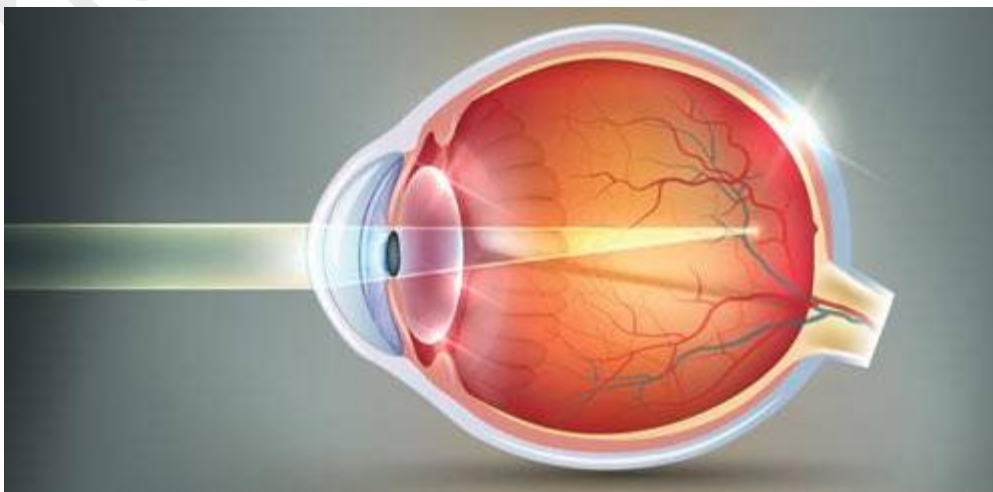
In Iraq:

- Recent studies among school-aged children show that **refractive errors affect approximately 27%** of students, and **myopia is the most common type**, accounting for nearly **35% of cases**.
- In a study from **Wasit (Al-Kut city)**, myopia prevalence among primary school children (ages 6–12) was around **16%**.
- These findings indicate that **Iraq is following the global upward trend**, with higher rates in **urban areas** such as **Baghdad, Najaf, and Karbala**, where screen use and limited outdoor activity are common.

Classification: Myopia can be classified by **severity** and **cause**:

▪ By Degree:

- ✓ Low myopia (approximately < -3.00 diopters)
- ✓ moderate myopia (-3.00 to -6.00 D)
- ✓ high myopia (> -6.00 D). High myopia carries a greater risk of ocular complications.



Causes of Myopia

❖ Based on Anatomical Features

1. Axial Myopia

- It is due to the relatively long axial length.
- 1 mm axial length lengthening will cause -3.00 D of myopia.

2. Curvature Myopia

- It is due to the decreased radius of curvature of the refractive surfaces, i.e., cornea and lens.
- 1 mm steepening will cause -6.00 D of myopia.
- It is found in keratoconus, lenticonus, and megalocornea.

3. Index Myopia

- It is due to an increase in the refractive index of the lens nucleus, which occurs in nuclear sclerosis.

4. Displacement of Refractive Element

- It is due to the forward displacement of the lens.

Symptoms of Myopia

- Blurry distance vision (while near vision may also be blurred up to a certain close range). A myopic person may struggle to read road signs or the chalkboard from the back of a classroom.
- Squinting to see distant objects clearly (narrowing the eyelids can temporarily improve focus).
- Eye strain (asthenopia) and headaches after trying to focus on distant details for long periods.
- Children with myopia might sit very close to the television or hold books very near to their eyes to see clearly.
- Frequent eye rubbing or blinking, as the child tries to clear the blur.

- In progressive or high myopia, the person may notice floaters or flashes of light in their vision (which could indicate vitreous traction on the retina). They might also report difficulty with night vision (night myopia) or glare sensitivity (Photophobia).
- Rapid Progression in Childhood or Adolescence.

Signs of Myopia

- **Refractive error on testing:** Distant vision is improved with minus (concave) lenses on a vision test. Retinoscopy or autorefractor readings will show a myopic refraction (e.g., – lenses needed).
- **Prominent eyes** with a slightly elongated appearance. Myopic eyes often have a **deeper anterior chamber** on exam and sometimes appear larger or protruding.
- **Large pupil:** Some myopic individuals have pupils that may appear dilated or wider in normal light. (This may be an adaptive result of chronic defocus, but is not always present.)
- **Fundus (Retinal) changes:** An ophthalmic exam may reveal a **myopic crescent** (an arc-shaped pale area near the optic disc where the retina has stretched). The retina may have **chorioretinal thinning** with tessellated (tigroid) fundus appearance in high myopia. Peripheral retinal **lattice degeneration** (thinned, lattice-like patches) can be found, predisposing to retinal tears.
- **Exophoria (latent outward squint):** Because myopes focus easily at near, there can be a tendency for the eyes to drift outward when looking at distance (a latent divergent strabismus that may be observed with cover-uncover tests).

Correction of myopia

Myopia is corrected by diverging light before it reaches the retina, which can be achieved with lenses or surgery:

- **Eyeglasses:** The simplest and most common correction. Glasses use concave (minus) spherical lenses to diverge incoming light rays, moving the focal point back onto the retina. The lens power (in diopters) is chosen to counteract the eye's refractive error exactly. Glasses are safe and effective, though high prescriptions can cause lens thickness and edge distortion.

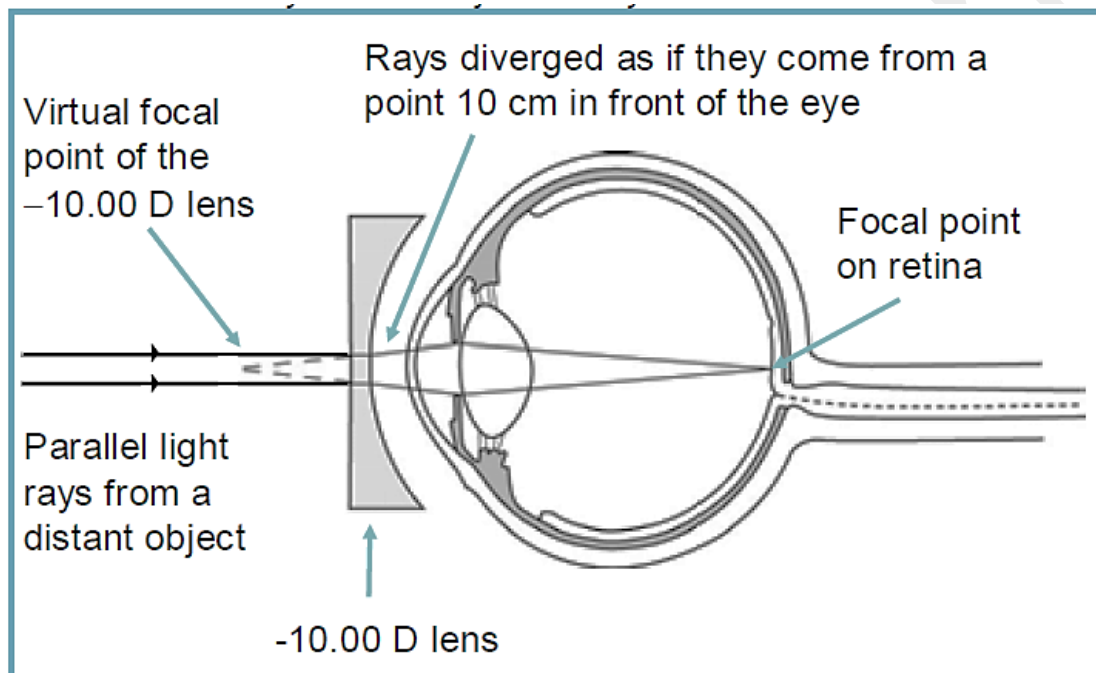


Figure: You can see that the -10.00 D lens diverges the light rays before they reach the eye – as if they were coming from a point 10 cm in front of the eye.

- **Contact Lenses:** Worn directly on the cornea, contact lenses also use minus power to correct myopia. They often provide a wider field of view and less distortion than glasses. Soft contact lenses are common for myopia; Rigid Gas Permeable (RGP) lenses can also correct myopia and may slow progression in some cases by influencing corneal shape.
- **Orthokeratology (Ortho-K):** A non-surgical intervention using specialized RGP contact lenses worn overnight to reshape the cornea temporarily.

Upon removing the lenses in the morning, the cornea retains an altered shape that corrects mild to moderate myopia during the day. The effect is reversible, and when lenses are not worn, the cornea returns to its original shape. Ortho-K can provide daytime freedom from glasses and may slow myopia progression by reducing peripheral defocus

Refractive Surgery:

- **LASIK (Laser-Assisted In Situ Keratomileusis):** is a common procedure where a thin corneal flap is created and a laser ablates corneal tissue underneath to flatten the cornea, correcting the myopia.
- **PRK (Photorefractive Keratectomy):** also uses an excimer laser to reshape the cornea, but without a flap – the epithelium is removed and regenerates. It is suitable for those with thinner corneas.
- **SMILE (Small Incision Lenticule Extraction):** is a newer technique where a femtosecond laser creates a small lens-shaped piece of tissue (lenticule) within the cornea, which is removed through a tiny incision, thereby flattening the cornea. These laser procedures can correct low to high myopia (within safe limits of corneal tissue removal).
- **Other surgeries:** For very high myopia or when corneal laser is not indicated, phakic intraocular lenses (IOLs) can be implanted to add negative power inside the eye, or refractive lens exchange (removing the eye's natural lens and replacing it with a corrective intraocular lens) can be considered. These are typically reserved for extreme cases or when the patient also has a cataract, due to higher risk profiles.

Complications and Associated Pathologies of Myopia

Higher degrees of myopia are associated with structural eye changes that increase the risk of various ocular pathologies. These include:

- **Retinal Detachment:** In myopic eyes, the elongated globe stretches and thins the retina. Peripheral retinal thinning (e.g., lattice degeneration) is common and can lead to retinal tears. Consequently, retinal detachment (the retina peeling away from the back of the eye) is a serious risk, especially in high myopia. Patients may experience flashes or floaters as warning signs. Myopes should be advised to seek immediate care if these occur, since retinal detachment can cause permanent vision loss.
- **Myopic Macular Degeneration:** Also known as myopic maculopathy, this is degenerative damage to the central retina (macula) due to long-term stretching of the eye. It can cause progressive loss of central vision. High myopia can lead to atrophy of retinal layers and choroid in the macular area. This is becoming a leading cause of blindness in regions with many high myopes. Signs include macular thinning and Fuchs spots (pigmented scars on the macula due to neovascularization).
- **Glaucoma:** Myopia increases the risk of open-angle glaucoma. The mechanism isn't fully clear, but elongated eyes may have structural differences in the optic nerve that make them more susceptible to glaucomatous damage. Studies show the risk of glaucoma is elevated in myopes. Regular intraocular pressure checks and optic nerve exams are important in patients with moderate to high myopia.
- **Cataracts:** Myopic patients tend to develop certain cataracts at younger ages, particularly posterior subcapsular cataracts. There is also an observation that as the lens nucleus hardens (nuclear sclerosis in older age), it can induce a myopic shift (often called "second sight"). High myopes are more prone to needing cataract surgery earlier, and surgical calculations for intraocular lens power must account for the long eye length.

- **Choroidal Neovascularization:** In pathological myopia, new fragile blood vessels can grow from the choroid (the vascular layer under the retina) into the retina – similar to wet macular degeneration. This myopic CNV can bleed and cause central vision loss. It often requires treatment with anti-VEGF injections. Even with treatment, it may lead to scar formation (Fuchs spot) at the macula.

Genetic and Environmental Risk Factors

Both heredity and environment contribute to myopia risk.

- **Family History:** Genetics play a significant role in predisposition to myopia. Children with one myopic parent are more likely to become myopic, and having two myopic parents amplifies the risk further. However, the rapid increase in prevalence cannot be explained by genetics alone – genes set the stage, but environment triggers expression.
- **Near Work:** Sustained near-vision tasks (reading, studying, using smartphones or computers at close distance) are strongly linked to myopia development. Prolonged accommodation (focusing up close) may induce retinal defocus signals that stimulate eye elongation. Populations with intensive educational demands and early schooling tend to have higher myopia rates. It's recommended to encourage regular breaks during near work (e.g., the 20-20-20 rule: every 20 minutes, look at least 20 feet away for 20 seconds) to reduce ciliary muscle strain and possibly lower myopia risk.
- **Lack of Outdoor Time:** Inversely correlated with myopia, higher time spent outdoors (especially in childhood) is protective. Bright natural light stimulates dopamine release in the retina, which may inhibit axial elongation. Studies have shown that children who spend more time outside each day have a lower incidence of myopia onset. Modern lifestyles with

more indoor activities (and screen time) have reduced outdoor exposure, contributing to the myopia surge.

- **Urbanization:** Growing up in urban environments is associated with higher myopia prevalence than rural settings. Urban children often have less outdoor space/time and more near-focused educational or entertainment activities. This lifestyle difference likely explains the urban-rural myopia gap.
- **Educational Pressure:** Early intensive schooling and high academic pressure correlate with myopia. For instance, countries with rigorous early education and heavy homework loads report more myopic students. The effect is partly due to increased near work and reduced outdoor time that come with academic work.
- **Other Factors:** Some evidence suggests that inadequate lighting or smaller living spaces may contribute (fewer opportunities to focus far away). Nutritional factors are not a primary cause of myopia, though overall eye health benefits from a good diet. There is ongoing research into whether reading distance (holding material very close) or screen viewing distance affects myopia progression – maintaining a reasonable working distance (≥ 30 cm for reading) is advised. Also, the age of onset is important: the younger a child becomes myopic, the higher the eventual progression tends to be. Thus, anything that delays onset (like outdoor activity) can greatly reduce final severity.

HOME WORK

1. Define myopia and explain how it affects the focusing of light inside the eye.
2. List and briefly describe the three main degrees (levels) of myopia according to refractive power.
3. Explain how axial elongation leads to myopia and mention the approximate diopter change per 1 mm increase in axial length.
4. What are the main symptoms that help differentiate myopia from other refractive errors?
5. Describe two anatomical signs of myopia that may be observed during an eye examination.
6. Compare LASIK, PRK, and SMILE surgeries in terms of procedure and corneal effect.
7. Explain why high myopia increases the risk of retinal detachment and other ocular diseases.
8. Identify and explain two environmental factors that contribute to the rising prevalence of myopia among children.
9. Discuss the prevalence and trend of myopia in Iraq, mentioning approximate percentages reported among school children.
10. Suggest at least two preventive or control strategies that can help reduce myopia progression in children.



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Second Stage 2025-2026

REFRACTIVE ERRORS 1

Lecture Title
Hypermetropia

Lecture Number: 6 / course 1

Prepared by
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Hypermetropia

Hypermetropia, or **farsightedness**, is a common refractive error where distant objects can be seen more clearly than near objects. It occurs when the optical power of the eye is insufficient relative to its length – typically because the eyeball is too short or the cornea's curvature is too flat, causing incoming light to focus behind the retina instead of directly on it. Many infants are born with mild hyperopia (due to their small eyes), which often diminishes as the eye grows toward an emmetropic (normal) state. However, if significant hyperopia persists or if the eye cannot adequately compensate by focusing, close-up vision remains blurry without corrective lenses.

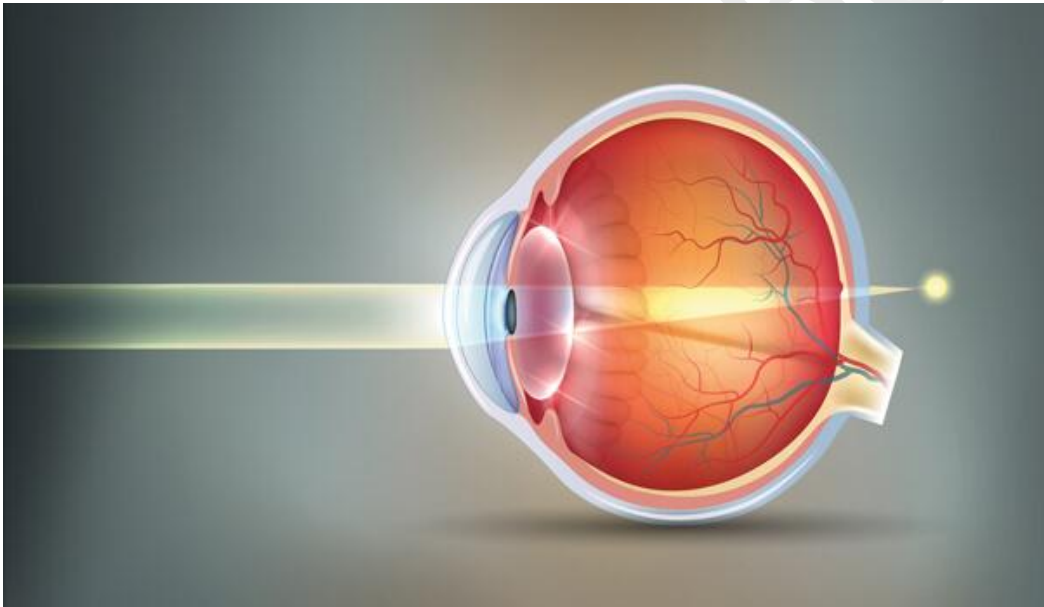


Figure: A hyperopic eye - light rays from a distant object focus behind the retina

Classification by Degree

- **Low Hypermetropia:** +2.00 diopters or less; usually mild symptoms.
- **Moderate Hypermetropia:** Between +2.25 and +5.00 diopters; more noticeable vision issues for close tasks.
- **High Hypermetropia:** Greater than +5.00 diopters; significant difficulty with near vision and possibly distant vision, often requiring strong corrective lenses.

Causes of Hypermetropia

❖ Based on Anatomical Features

1- Axial Hypermetropia

- It is due to the relatively short axial length.
- 1 mm axial length shortening will cause +3.00D of hypermetropia.
- Physiologically, the majority of all infants are axially hypermetropic due to the small size of the globe at birth.
- Pathologically, axial hypermetropia will develop when the retina is pushed forward in ocular tumour, central serous retinopathy, etc.

2- Curvature Hypermetropia

- It is due to the increased radius of curvature of the refractive surfaces, i.e., cornea and lens.
- 1 mm increase in radius of curvature, i.e., flattening, will cause +6.00D of hypermetropia.
- It is seen in cornea plana.

3- Index Hypermetropia

Results from changes in the refractive index of the ocular media, usually the lens. In older adults (or sometimes in diabetics under tight blood sugar control), the outer layers of the lens can have a higher refractive index relative to the nucleus, reducing the lens's overall converging power. This age-related change (often early in the cataract formation process) causes the eye to become more hyperopic (sometimes called a hyperopic shift), the opposite of the myopic shift typically seen in nuclear cataracts.

4- Absence of lens (aphakia)

Removal or absence of the crystalline lens eliminates a major focusing element of the eye. Aphakia (whether from surgical removal, injury, or congenital absence of the lens) leaves the eye highly hypermetropic, often on the order of

+10 diopters or more, because the cornea alone is too weak to focus light on the retina.

5- Positional (displacement of lens)

If the crystalline lens is displaced backward (posteriorly) within the eye, its effective power is reduced, causing hypermetropia. This can occur due to trauma or developmental anomalies that alter the normal position of the lens. (By contrast, an anteriorly dislocated lens would increase optical power and induce myopia.)

❖ Accommodation-based Classification

The role of the eye's focusing muscle (the ciliary muscle) and its ability to accommodate (change the lens shape) leads to different functional types of hypermetropia

1- Latent hypermetropia

The eye's normal accommodative tone masks this portion of farsightedness. The ciliary muscle, even at rest, provides a bit of focusing power that "hides" some hyperopia. Latent hypermetropia is not apparent in a regular refraction exam because the eye's automatic focus is compensating for it. It can only be unmasked by fully relaxing accommodation, typically using cycloplegic eye drops during an exam. In young people with strong accommodation, about +1 diopter (sometimes more) of hyperopia can remain latent. This latent component tends to decrease with age as the accommodative ability wanes.

2- Manifest hypermetropia

This is the portion of hyperopia that can be detected without cycloplegia – i.e. the refractive error evident when the patient's accommodation is either minimal or only partially engaged. Manifest hypermetropia is further composed of:

- a. Facultative hypermetropia:** the part of manifest hyperopia that can be voluntarily overcome by accommodation. A patient with facultative hyperopia might see clearly at distance by focusing their eyes (engaging accommodation). This means they don't necessarily need glasses for

distance vision when they are young and their accommodative reserve is strong. Facultative hyperopia becomes evident on a normal (non-cycloplegic) refraction test, but the patient may not notice symptoms because their eyes adjust for it.

This type of hyperopia is common in younger individuals because they have a stronger accommodative power.

- b. Absolute hypermetropia:** the portion of hyperopia that cannot be compensated for by accommodation. If a person's hyperopic error exceeds what their focusing muscles can counteract, that excess is absolute hyperopia – it causes blurred distance vision unless corrective lenses are used. Clinically, absolute hyperopia is measured as the weakest convex (plus) lens that allows the patient to achieve 20/20 (6/6) distance vision. Any required hyperopic power beyond that is, by definition, beyond their accommodative ability.

Absolute hyperopia is common in people with moderate to high levels of hyperopia or in older individuals whose accommodative power has declined (often due to presbyopia).

Total hypermetropia = latent hypermetropia + manifest hypermetropia (facultative + absolute).

- In young children, the hypermetropia represents latent hypermetropia.
- Age advances, the lens become less elastic and it changes towards manifest hypermetropia.
- Older the subject, the more the manifest hypermetropia.

Symptoms of Hypermetropia

Mild hypermetropia often goes unnoticed until later in life, but more pronounced cases (or as accommodative capacity declines) can produce various symptoms:

- **Blurry near vision:** Difficulty in reading small print, doing close work, or using devices at close range is common. Distant objects may remain clear, especially in low or moderate hyperopia.
- **Eye strain and fatigue:** Sustained near tasks (reading, computer use) demand constant accommodative effort in a farsighted eye. This often leads to **asthenopia** – tired, sore eyes and a feeling of strain, especially later in the day or after prolonged focusing. Patients may rub their eyes frequently or complain that their eyes feel fatigued with near work.
- **Headaches (frontal headaches):** A dull frontal or brow ache is a frequent complaint, caused by chronic contraction of the ciliary muscle during near focusing. Neck pain can also occur from prolonged tensing or squinting. These headaches often worsen with extensive reading or other close work and may improve with rest or with proper glasses.
- **Difficulty with prolonged near tasks:** Because of the effort required to maintain focus, hyperopic individuals (especially those with only facultative hyperopia) may find that after some time, print becomes blurry or they lose concentration when reading. They might need to take frequent breaks.
- **Squinting:** Some people unconsciously squint when trying to see up close, as squinting creates a pinhole effect that can temporarily improve focus. Children with uncorrected hyperopia might squint or frown when looking at near objects or reading.

- **Convergent squint in children:** Significant uncorrected hyperopia in children can lead to an *accommodative esotropia* – an inward turning of one or both eyes when focusing on near objects. This happens because the strong accommodative effort is linked to excessive convergence (crossing) of the eyes. Parents may notice a child's eye turning inward, especially during tasks like reading or when the child is tired.
- **Latent convergent squint (esophoria):** Even if a constant strabismus (squint) is not present, children with hyperopia may tend for their eyes to drift inward when the fusion mechanism is disrupted (for example, covering one eye). This **esophoria** is a latent convergence that can be revealed by covering one eye (cover test). It indicates the visual system is working hard to keep the eyes aligned, and without correction, these children are at risk of a manifest squint.
- **Intermittent blurred distance vision after near work (pseudomyopia):** After doing close work for a long time, a hyperopic person (especially a teenager or young adult) might experience a temporary difficulty focusing on distant objects – things far away become blurry for a short while. This is due to a transient spasm of accommodation from overuse, sometimes called **pseudomyopia**. Essentially, the eye “locks” in a focusing state for near vision and is slow to relax for distance. After rest, distance vision clears again. This symptom suggests uncorrected hyperopia with overexertion of the focusing system.

Signs of Hypermetropia

Certain clinical signs and exam findings are characteristic of hyperopia, especially high hyperopia:

- **Small eyeball & shallow anterior chamber:** Farsighted eyes, particularly with axial hypermetropia, tend to have shorter anterior-posterior length. An ophthalmologist may note that the eye appears slightly smaller than average. This also results in a **shallow anterior chamber** (the space in the eye between the cornea and the iris/lens). A shallow chamber is significant because it predisposes the eye to narrow angles, increasing the risk of angle-closure glaucoma (see complications). The anterior segment exam of a high hyperope often shows an anterior chamber depth that is shallower than normal.
- **Fundoscopy hyperopic changes:** On ophthalmoscopic examination, hyperopic eyes can exhibit a *crowded optic disc*. The optic nerve head in high hyperopia often appears small and somewhat blurred at the margins, with blood vessels that seem crowded as they exit the disc. This appearance can simulate mild optic disc swelling. In fact, a **small hypermetropic disc with indistinct margins** is a pseudo-papilledema (also called **pseudopapillitis**) – it can be mistaken for optic nerve swelling. Still, in hyperopia, it's simply due to the anatomy of a small eye. Another classic fundus finding is an increased brightness of the retinal reflex known as a **“shot-silk” (or watered silk) appearance** of the fundus. This refers to a shiny, striated reflection from the retina/choroid often seen in hyperopic eyes due to the way light reflects off the fine folds in the retinal pigment epithelium and choroid of a smaller eye.
- **Amblyopia (functional vision loss):** Although not visible as a structural change, **amblyopia** (lazy eye) is more frequently associated with uncorrected hypermetropia, especially if the hyperopia is high or significantly

unequal between the two eyes. A child with one eye that is much more hyperopic than the other may start to favor the clearer eye, leading the weaker eye's visual development to lag. High bilateral hyperopia can also cause **ametropic amblyopia** in both eyes if the retinal images are chronically out of focus during childhood. On an eye exam, reduced best-corrected visual acuity in one or both eyes (not due to any retinal or optic nerve pathology) could indicate amblyopia secondary to hyperopia.

- **Strabismus:** As noted, accommodative **esotropia** (inward turning of the eye) is a common consequence of significant hyperopia in children. During the exam, the physician might observe a constant or intermittent convergent squint, especially when the child attempts to fixate on a nearby target without glasses. There is also a scenario of *apparent divergent squint* in some hyperopic children. In certain cases, the optical properties of a hyperopic eye can create an illusion of a slight outward deviation (for example, a pseudo-exotropia due to wide-set eyes or a flat nasal bridge can give a false impression of divergence). However, true divergent strabismus (exotropia) is less common in hyperopia than convergent strabismus.
- **Visual acuity can be surprisingly normal (in youth):** Young patients with moderate hypermetropia may still read the 20/20 line on a distance eye chart during a routine exam by exerting accommodative effort. Thus, a child or young adult might not show reduced visual acuity at distance. Yet, they could still be significantly hyperopic – their ciliary muscle is simply working overtime to maintain clarity. This underscores the importance of cycloplegic refraction in examining children: to relax the accommodation and reveal the full hyperopic error.

Risks and Complications

Uncorrected or high hypermetropia can lead to several **complications**:

- **Amblyopia:** As mentioned, chronic unfocused images on the retina during childhood can cause the visual system to “turn off” an eye. Both **anisometropic amblyopia** (one eye amblyopic due to asymmetrical refractive error) and **ametropic amblyopia** (both eyes amblyopic from high bilateral refractive error) are risks in hypermetropia. Early detection and correction of hyperopia is critical to prevent permanent vision development issues.
- **Strabismus (Accommodative Esotropia):** Farsighted children are at risk of developing a convergent squint. Because focusing (accommodation) is linked with eye convergence, excessive focusing effort can pull the eyes inward. This **accommodative convergent squint** typically presents as an inward deviation (esotropia) when the child looks at near objects, and sometimes even at distance if severe. Correcting the hyperopia with glasses often straightens the eyes by relieving the over-accommodation. Persistent strabismus may require vision therapy or strabismus surgery in addition to optical correction.
- **Primary angle-closure glaucoma (PACG):** Hyperopic eyes are anatomically predisposed to narrow-angle structures in the eye. The shallow anterior chamber and crowded anterior segment can lead to the iris blocking the trabecular meshwork, especially as the lens enlarges with age. Thus, **angle-closure glaucoma** is more common in hyperopic individuals. For example, populations with shorter eye anatomies (such as some East Asian groups) have higher rates of angle-closure, partly due to hyperopic ocular dimensions. Hyperopic patients should have their anterior chamber angle assessed (e.g., via gonioscopy) to evaluate this risk, especially if they

are high hyperopes or have symptoms like intermittent eye pain with blurred vision (which could indicate intermittent angle closure).

- **Other associations:** Studies have noted associations between hyperopia and certain ocular conditions. For instance, uncorrected hyperopia has been linked to an increased risk of **refractive accommodative esotropia** (as discussed) and even a higher incidence of **secondary complications** like *recurrent styes or conjunctivitis* (possibly from eye rubbing due to fatigue). Extremely small hyperopic eyes (nanophthalmos) are prone to uveal effusion and choroidal folds. There is also some evidence that hyperopia may correlate with a higher risk of age-related macular degeneration and vein occlusions. However, these associations are not as prominent as the risk of angle-closure glaucoma and strabismus. The primary take-home, however, is that **early correction and monitoring** can mitigate many of these risks by ensuring proper visual development and checking for complications.

Diagnosis of Hypermetropia

Hyperopia is typically identified during a **comprehensive eye examination**. Key components of diagnosing farsightedness include:

- **Visual Acuity Testing:** Both distance and near vision are tested (e.g., reading a Snellen chart at 6 m and a near card at 30–40 cm). A hyperopic person might read the distance chart well (especially if young and the hyperopia is moderate), but may struggle with the near card. In higher hyperopia or older patients, distance acuity may also be reduced. Any discrepancy between distance and near acuity can hint at a focusing issue.
- **Refraction Assessment:** Using a **phoropter** or **autorefractor**, the examiner determines the lenses that correct the patient's vision. This can be

done subjectively (asking the patient which lens makes the chart clearer) and objectively. **Retinoscopy** is an important objective technique: the clinician shines a light into the eye and uses lenses to “neutralize” the reflex, thus measuring the refractive error. Hyperopia is indicated when **convex (plus) lenses** are needed to focus light on the retina. Often, a tentative refraction is first measured without drops (this finds the manifest hyperopia).

- **Cycloplegic Refraction:** Because of latent hypermetropia in younger patients, **cycloplegic eye drops** (such as atropine, cyclopentolate, or tropicamide) are used to paralyze accommodation temporarily. After cycloplegia, a second refraction is done – this reveals the **total hyperopia**, including the latent portion that was previously compensated by the ciliary muscle. Cycloplegic refraction is **essential in children** and young adults when hyperopia is suspected, especially if they have crossed eyes or symptoms like headaches. It ensures that no significant hyperopia is missed and that the full correction can be prescribed if needed. (In practice, a **wet retinoscopy** after dilation often uncovers an extra +1 to +2 diopters of hyperopia that the patient was masking.)
- **Ocular Examination:** A slit-lamp exam and **ophthalmoscopy** (fundus exam) are performed to assess the health of the eyes. While these do not measure refraction, they can identify signs associated with hyperopia (as noted in the signs section, e.g., small optic discs, shallow anterior chamber) and rule out other ocular pathology. The examiner will also check eye alignment and movement. Cover tests can detect latent or manifest strabismus that might be related to hyperopia. **Angle assessment** (e.g., by gonioscopy or anterior segment OCT) may be done in known high hyperopes to evaluate the risk of angle-closure.
- **Autorefractor/Phoropter measurements:** An **autorefractor** is a machine that provides an automated estimate of the refractive error by measuring light

reflections in the eye. This is often used as a starting point. A manual refraction with a phoropter refines these measurements and determines the best corrective lenses for clear vision. In hyperopia, the “best” lens is the strongest plus lens that gives maximum clarity. As a check, the optometrist/ophthalmologist will typically ensure that giving any additional plus power starts to blur distance vision, confirming the correct endpoint.

Management and Correction of Hypermetropia

The goal of treatment is to provide clear, comfortable vision and prevent complications. **Most hyperopia can be fully corrected with optical lenses** (glasses or contacts), which converge light rays sooner so they focus on the retina. In certain cases, refractive surgery or intraocular lens solutions are employed. Management must also be tailored to the patient's age, degree of hyperopia, and symptoms.

1. Eyeglasses (Spectacles): Prescription glasses with **convex (+) lenses** are the simplest and safest way to correct hypermetropia. The convex lens adds focusing power to the eye, moving the focal point forward onto the retina. The lens power (measured in diopters) is chosen to neutralize the hyperopic error. Key considerations:

- **Full vs partial correction:** In children, **full hyperopic correction** is often prescribed, especially if they have strabismus or symptoms. The total hyperopia is determined with cycloplegic refraction, and the full value is incorporated into the glasses so the child's eyes are properly focused without straining. This not only sharpens vision but also helps straighten accommodative esotropia and reduces the risk of amblyopia. Young children with eye turns (esotropia) should receive the **full cycloplegic refraction** correction as early as possible. In contrast, a young adult with low hyperopia and no symptoms or squint might not need glasses at all for distance – they

can often compensate on their own. The practitioner may choose to prescribe nothing or a reduced prescription in such cases (and advise rest or reading glasses as needed).

- **Manifest vs absolute hyperopia in adults:** An older patient (or anyone with symptoms) typically benefits from correction. The **strongest plus lens that still allows clear distance vision (20/20)** is used to determine the *manifest hyperopia*. Within that manifest portion, the **weakest plus lens that gives 20/20** represents the *absolute hyperopia*, and any additional plus power up to the strongest clear lens is the facultative part. In practice, eye doctors will often push plus lenses until the patient starts to blur at distance, then back off a step – this yields the maximum plus (manifest) that the person can accept without compromising distance vision. The difference between that and the clarity threshold defines how much the patient was accommodating. **Example:** If a patient sees 20/20 with +1.00 D and still 20/20 with +2.00 D, but blurs with +2.25 D, then +2.00 is manifest. If they needed at least +0.75 D to see 20/20, then +0.75 D is absolute, and the remainder (+1.25 D) was facultative. These details guide the amount of power to prescribe, especially if the patient is not yet presbyopic. (Facultative hyperopia might be left uncorrected in some cases if the patient can handle it, but generally, if symptoms exist, one prescribes the full manifest correction.)
- **Near additions:** Older hyperopic patients (usually over 40–45) will also require a **presbyopic add** in their glasses for reading. This is because even after the hyperopia is corrected for distance, they have lost the ability to accommodate for near. Often, hyperopes notice presbyopia earlier than emmetropes, because they've been “using up” their accommodation to overcome hyperopia. Bifocals or progressive lenses are commonly prescribed, with the top part of the lens correcting the distance hyperopia and the lower segment providing additional plus for near work.

- **Glasses in children without symptoms:** There is some nuance: small amounts of hyperopia in children without strabismus may not need immediate correction. Ophthalmology guidelines often set thresholds based on age and magnitude (for example, a 3-year-old might not be given glasses for +1.00 D hyperopia if they are not crossing or symptomatic, whereas +4.00 D would be corrected). The key is regular monitoring. Many children “grow out” of mild hyperopia as their eyes lengthen. Glasses are usually prescribed if hyperopia is high for age, if the child has an eye turn, or if they report symptoms like headaches. **Follow-ups** every 6–12 months are important to adjust the prescription as the child grows.

2. Contact Lenses: Contact lenses can also correct hyperopia by adding the necessary converging power on the eye's surface. Contacts have some advantages: they provide a wider field of view and avoid the magnification and aberrations that thick plus glasses can cause. They are especially useful in cases of **anisometropia** (unequal refractive error between eyes) – for example, if one eye is +5 and the other is +1, glasses would produce significantly different image sizes on each eye (aniseikonia), which the brain may not fuse well. A contact lens, being on the eye, minimizes image size differences. Thus, **unilateral hypermetropia or large differences between eyes** are often better managed with a contact lens on the more hyperopic eye. Contacts are also helpful for athletes or others who cannot easily wear glasses. On the downside, contacts require proper hygiene and come with risks like infection or dry eyes. In children, contact lens use is usually reserved for special cases (like aphakia or high anisometropia) because it requires mature handling and parental support.

3. Refractive Surgery: For appropriate candidates, surgical correction of hyperopia is an option to reduce dependence on lenses. Surgical methods aim to **reshape or replace an optical component** to refocus light on the retina:

- **Laser corneal surgery (LASIK/LASEK/PRK):** Laser vision correction can be used for mild to moderate hyperopia. In **LASIK (Laser-Assisted In Situ Keratomileusis)**, a laser is used to remove corneal tissue in a ring pattern to steepen the cornea, thereby increasing its refractive power for the hyperopic eye. LASIK is generally effective for hyperopic corrections up to around +4.00 D (higher corrections have less predictable outcomes). The Cleveland Clinic notes that LASIK is typically for lower degrees of hyperopia. **LASEK** and **PRK** are surface ablation techniques (no corneal flap) that can similarly reshape the cornea for hyperopia; they might be chosen if the cornea is too thin for LASIK. Patients undergoing laser correction must have stable refractions and healthy eyes. These procedures can successfully reduce or eliminate the need for glasses in many farsighted individuals, though they carry typical surgical risks and may temporarily induce dry eye or halos. Technological advances (like customized wavefront-guided lasers) have improved outcomes for hyperopic LASIK in recent years.
- **Conductive Keratoplasty (CK):** This is a less common, older technique that uses radiofrequency energy to shrink peripheral corneal collagen, steepening the central cornea. It was approved for treating low hyperopia (up to +3 D) and presbyopia in non-dominant eyes. However, its effect can be temporary, and it has largely fallen out of favor compared to LASIK/PRK.
- **Refractive Lens Exchange (RLE):** Also known as clear lens extraction, this is essentially the same procedure as cataract surgery but done electively for refractive reasons. Here, the natural crystalline lens (which in hyperopes may be too weak or cause high farsightedness) is removed, and an artificial intraocular lens (IOL) of appropriate power is implanted. This is often considered for **high hypermetropia** (e.g., +6 D, +8 D, etc.), especially in older adults. The advantage is that any degree of refractive error can be corrected by selecting the right IOL power, and it also preempts future cataract development. The downside is that, as in cataract surgery, the eye

loses its ability to accommodate (if it hadn't already from age), so the patient will need reading glasses or a multifocal/extended-depth-of-focus IOL to address near vision. RLE carries the surgical risks of intraocular surgery and is generally not performed in young patients if other options are viable.

- **Phakic Intraocular Lenses (Phakic IOLs):** In cases of high hyperopia in younger patients who still accommodate, an alternative to implanting an additional lens in the eye without removing the natural lens. These **implantable contact lenses** (e.g., angle-supported, iris-fixated, or posterior chamber phakic IOLs) can correct high refractive errors. Phakic IOLs are often used for high myopia, but there are models to correct hyperopia as well. They preserve the eye's natural lens (and thus accommodation for the time being). However, phakic IOLs have their own risks, such as endothelial cell loss or cataract formation. They are typically considered when the hyperopia is beyond the safe range of corneal laser surgery.

4. Vision Therapy and Others: While glasses or surgery address the optical error, some patients (particularly children) may benefit from additional interventions. For instance, if amblyopia has developed, **occlusion therapy** (patching the stronger eye) or penalization can help improve the weaker eye's vision alongside the use of proper glasses. If strabismus persists even with glasses or prism lenses, strabismus surgery might eventually be indicated. Ensuring good **lighting and working distance** for near tasks, taking breaks during reading (to reduce accommodative spasm), and treating any associated conditions like convergence insufficiency or accommodative spasm (sometimes with short-term bifocals or even pharmacologic cycloplegia) can all be part of comprehensive management.

HOME WORK

1. What is hypermetropia (farsightedness) and how does it affect the focusing of light in the eye?
2. Classify hypermetropia by degree and give the diopter range for each category (low, moderate, and high hypermetropia).
3. List three major causes of hypermetropia related to the eye's structure or optics, and briefly explain how each cause leads to farsightedness.
4. Explain the terms latent hypermetropia, facultative hypermetropia, and absolute hypermetropia (the components of total hypermetropia).
5. Name three common symptoms of uncorrected hypermetropia and explain why each of these symptoms occurs.
6. How can significant uncorrected hypermetropia in a young child lead to strabismus, and what type of strabismus is most commonly associated with this condition?
7. Mention two clinical signs that an eye doctor might observe during an exam of a patient with high hypermetropia.
8. Why are individuals with high hypermetropia at increased risk of primary angle-closure glaucoma?
9. Why is a cycloplegic refraction (using dilating eye drops to relax focus) important when examining a young patient for hypermetropia?
10. List two surgical or lens-based treatment options for high hypermetropia (aside from regular glasses or contact lenses) and briefly describe one of them.



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Second Stage 2025-2026

REFRACTIVE ERRORS 1

Lecture Title
Visual Acuity

Lecture Number: 7 / course 1

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Visual Acuity (VA)

Definition and Importance

Visual acuity refers to the eye's ability to perceive fine detail and resolve small separations between objects. It is one of the most fundamental measures of visual function and is commonly tested in eye exams. As a **subjective** test, measuring VA relies on patient cooperation and responses: the patient must identify symbols (letters, numbers, or shapes) on a chart while the examiner records the smallest detail the eye can discern. Despite being simple, VA testing is crucial for detecting refractive errors and ocular health issues, and it is often the first test performed in a routine eye examination.

Expressing Visual Acuity (Snellen Fraction)

Visual acuity is typically recorded as a fraction (Snellen fraction) comparing the tested eye's performance to that of a normal eye. The **numerator** represents the distance at which the test is performed, and the **denominator** is the distance at which a person with normal vision could identify the same target. For a standard test distance of 6 meters (or 20 feet):

$$VA = \frac{\text{distance at which the patient person sees the target}}{\text{distance at which the healthy person sees the target}}$$

- "6/6" (*metric*) or "20/20" (*US*) indicates normal acuity – the patient can see at 6 m what a normal eye sees at 6 m.
- "6/18" (20/60) means the patient must be at 6 m to see what a normal eye can see from 18 m (visual acuity is reduced to one-third of normal).
- "6/60" (20/200) means the patient sees at 6 m what a normal eye discerns at 60 m – a level of vision considered **legal blindness** in some countries.

For convenience, acuity is often tested at 6 m or 20 ft, and common Snellen equivalents in meters vs feet are:

Snellen (Metric, 6 m base)	Snellen (US, 20 ft base)	
6/60	20/200	1
6/48	20/160	2
6/36	20/120	3
6/24	20/80	4
6/18	20/60	5
6/12	20/40	6
6/9	20/30	7
6/6	20/20	8

In general, the smaller the fraction (with a larger denominator), the poorer the resolution. For example, if a person's VA is recorded as 6/18, it means they must be at 6 m to read a line that a person with normal 6/6 vision could read at 18 m. Conversely, a fraction like 6/4 (20/15) would indicate **better than normal** acuity.

Levels of Visual Impairment (WHO Classification)

The World Health Organization (WHO) defines categories of visual impairment based on best-corrected visual acuity:

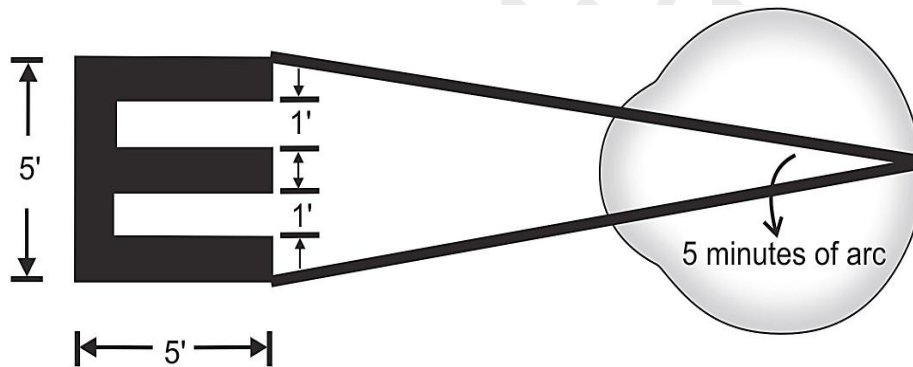
Visual Acuity Levels	Degrees of Visual Impairment
Mild Visual Impairment	Worse than 6/12 up to 6/18
Moderate Visual Impairment	Worse than 6/18 up to 6/60
Severe Visual Impairment	Worse than 6/60 up to 3/60
Blindness	Less than 3/60

These thresholds apply to the better eye with the best possible correction. (Note: Legal definitions of blindness can vary by country. For example, in the US, legal blindness is defined as 20/200 or worse in the better eye with correction, or a visual field no greater than 20°)

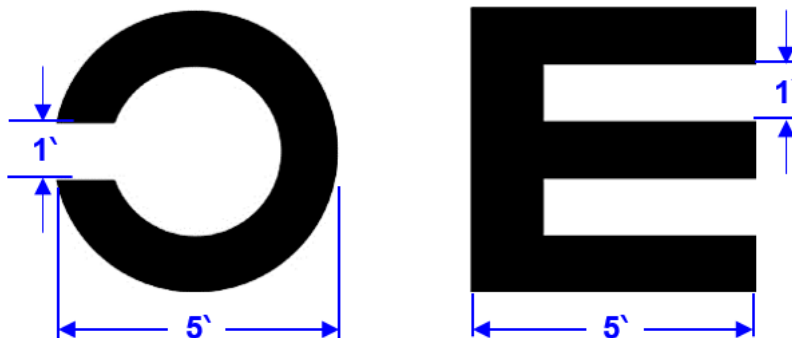
How Vision Charts Work: Optotypes and MAR

Visual acuity charts (like the familiar Snellen chart) are designed based on geometric and physiological principles. The goal is to have each line of the chart test a specific minimum angle of resolution (MAR) at the standard viewing distance. Key concepts include:

- **Optotypes:** The symbols on the chart (letters, E's, C's, shapes) are called optotypes. In a Snellen chart, each optotype is constructed on a 5x5 grid: the overall height and width of the letter is **5 times the stroke thickness**. For example, the letter "E" is made of black strokes and gaps of equal thickness, and the entire "E" is five strokes tall. This design ensures critical details of the letter (like the gap or stroke) can test the eye's resolving power.



- **Minimum Angle of Resolution (MAR):** A normal eye is considered able to resolve detail that subtends 1 arcminute (1/60 of a degree) at the eye. Snellen's standard "6/6" optotype is calibrated such that its *critical detail* (the thickness of the strokes and the gaps) subtends **1 minute of arc**, and the whole letter subtends **5 minutes of arc** at 6 m



- In practical terms, at 6 m, the 6/6 line letters are about 8.7 mm tall, because 8.7 mm/6 m corresponds to 5 arcminutes. A larger letter, like the big “E” at the top (6/60 line), is ~87 mm tall so that it subtends 5 arcmin at 60 m (or equivalently 50 arcmin at 6 m). Thus, as the viewing distance or desired acuity level changes, the required letter size changes proportionally to keep the same retinal image size. Mathematically, one can calculate the needed letter size (X) for an optotype at a given acuity line by:

$$X = R \cdot \theta$$

Where R is the distance at which that line is standardized (the denominator of the Snellen fraction) and θ is the minimum resolvable angle (~0.00029 radians, equal to 1 arcminute).

Types of Visual Acuity Measurements

When examining a patient's visual acuity, several measurements are typically taken to get a complete picture:

- **Distance Visual Acuity (DVA):** Clarity of vision at distance (usually tested at 6 m or 20 ft). This is what Snellen charts measure. It reflects how well the eye focuses parallel light (far vision) and is crucial for tasks like driving or seeing distant signs.
- **Near Visual Acuity (NVA):** Clarity of vision at reading or near distance (often tested at 40 cm/16 in with a near card). This relates to the eye's ability to focus on close objects and is important for reading, smartphone use, and other activities. Near acuity is typically recorded separately since some individuals may have good distance vision but poor near vision (e.g., presbyopia in older adults).
- **With or Without Correction:** Each acuity is measured both *with the patient's glasses or contact lenses (if any)* and *without correction*. *Uncorrected VA* indicates the baseline natural vision, while *best-corrected*

VA (with glasses/contacts or a pinhole) shows the potential vision if refractive error is fully corrected. This helps differentiate refractive blur from other causes of vision loss. When recording, the notation “**sc**” (sine correctione) is used for *without glasses* and “**cc**” (cum correctione) for *with glasses*.

- **Each Eye and Both Eyes:** Visual acuity is measured for each eye separately, **Right Eye (OD)**, then **Left Eye (OS)**, and sometimes **Binocular (OU)** with both eyes open. Testing monocular acuity is important to detect unilateral vision problems that could be masked when both eyes are used together. Binocular acuity can be slightly better due to binocular summation (the brain combining input from both eyes).

Thus, a typical VA documentation might read, for example: OD 6/9 (sc), OS 6/12 (sc); OD 6/6 (cc), OS 6/6 (cc). This indicates the right eye uncorrected was 6/9 and left 6/12, but with correction, each improved to 6/6. If a **pinhole (PH)** test is done, it is noted as well (e.g., PH 6/7.5 meaning acuity improved to 6/7.5 with a pinhole).

Procedure: Distance Visual Acuity Testing (Adults)

Assessing distance acuity in adults or older children follows a standardized approach:

1. **Patient Preparation & History:** Begin by recording any **visual complaints or history**. Note if the patient uses prescription glasses or contact lenses and for how long. If they have glasses, check the lens power (using a lensometer) to understand their current correction. This baseline helps to correlate their current corrected VA with their prescription.
2. **Chart Selection and Setup:** Use an appropriate **distance eye chart** (Snellen chart or similar) positioned **6 m** away from the patient (or use a mirror setup for smaller rooms). Ensure the chart is well-illuminated.

Typically, one eye is tested at a time. The patient should be seated or standing comfortably at the required distance.

3. **Use of Trial Frame or Phoropter:** If you plan to refine refraction or test with lenses, place a **trial frame** adjusted to the patient's pupillary distance (PD) and proper alignment. Alternatively, use the phoropter. But for an initial unaided test, no lenses are used except a plane occluder.
4. **Occlusion of One Eye:** Instruct the patient to **cover the left eye** (for example) with an occluder or their palm (without pressing on the eye). Ensure they are not peeking through their fingers. We usually test **Right Eye (OD)** first.
5. **Encourage Relaxed Gaze:** Ask the patient to keep both eyes open (one covered) and to **look at the chart**. Begin with the **largest letter** at the top (often the 6/60 or 6/90 letter, depending on the chart) to ensure the letter is visible. Confirm they can see something; if not, move them closer until they can, or proceed to low vision steps (described later).
6. **Sequential Line Reading:** Have the patient read **from the top line downward**. Typically: *"Please read the smallest line of letters you can see."* If they struggle, you can prompt starting from a larger line and then go down line by line. Monitor for squinting or head tilts. **Record the smallest line they can read at least half of the letters correctly** as their acuity for that eye. For example, if they read the 6/12 line fully but miss some on 6/9, you record VA = 6/12 (with a note of any misses).
7. **Refinement with Lenses:** If the test is being done *without correction* and the patient cannot achieve 6/6, you may use a **pinhole or trial lenses** to see if vision improves. The **pinhole test** is a quick way to check for refractive error – the pinhole allows only central rays, reducing blur from focus errors. An improvement through pinhole (e.g., from 6/18 to 6/6) suggests that with

proper glasses, the patient could see 6/6. In contrast, no improvement (PHNI – pinhole no improvement) might indicate an underlying pathology rather than just refractive error. Alternatively, place trial lenses in front of the eye (start with approximate power based on their glasses or retinoscopy) and adjust until the best acuity is found.

- 8. Repeat for the Other Eye:** Cover the right eye and test the **Left Eye (OS)** in the same manner, recording the acuity.
- 9. Binocular Acuity:** Optionally, test **both eyes together (OU)** by uncovering both eyes and noting if the acuity improves. Often, binocular VA can be a line better due to the two eyes complementing each other.
- 10. Record Findings:** Document the acuity for each eye, noting whether it's unaided or with correction. For example: VA (*without glasses*): OD 6/18, OS 6/24; VA (*with current Rx*): OD 6/9, OS 6/12; VA (*with new refraction*): OD 6/6, OS 6/6. If a pinhole was used: OD 6/9 PH 6/6 (meaning 6/9 unaided improved to 6/6 with a pinhole). This documentation is typically written on the exam chart or prescription pad. It's also important to note if the patient was wearing their habitual correction during the test.

Assessing Very Low Vision (Below Chart Range)

What if the patient cannot even see the largest optotype (the big “E” or top letter) on the chart at 6 m? In such cases, the examiner moves to a sequence of **reduced-distance and gross vision tests**, documenting the results in a standard hierarchy:

- 1. Reduce Test Distance:** First, move the patient closer to the chart (e.g., from 6 m to 3 m or 1 m) to see if they can identify the big letter at a shorter range. If they can locate it at, say, 1 m, you might record VA as 1/60 (using

“meters/tested distance” convention). Often, however, for consistency, other methods are preferred once beyond the chart range.

2. **Count Fingers (CF):** Stand about **1 meter** in front of the patient (or some standardized distance) and hold up a certain number of fingers against a contrasting background. Ask if they can **count your fingers**. For example, “How many fingers am I holding up?” Test with varying numbers (1, 2, 5, etc.). If the patient can accurately count fingers at 1 m, you record “*CF @ 1 m*” (or whatever distance was used). If not, proceed to the next step. *Counting Fingers* gives a rough acuity estimate (some have tried to equate it to a Snellen equivalent, but it’s not standardized. It’s important to note the distance (e.g., CF @ 2 ft or CF @ 1 m) because being able to count at a closer distance indicates worse acuity than at a farther distance.
3. **Hand Motion (HM):** If the patient cannot count fingers even at close range, test for perception of gross **hand movement**. Wave your hand slowly a foot or two in front of their face and ask if they can detect any movement. Record as “*HM*” (hand motion) and the distance (though often, if it’s just in front of the face, distance may be omitted or noted as “HM @ 30 cm”). This assesses if the eye can detect motion and light changes. If the patient cannot see hand waving, go further down.
4. **Light Perception (LP):** In a dim or darkened room, use a **penlight** or ophthalmoscope light and test if the patient can perceive light. Shine the light toward the patient’s eye from different directions and ask if they see a light or not (and sometimes where the light is coming from). If they can detect the light at all, record “*LP*” (light perception). Some clinicians specify *LP with projection* if the patient can also discern the direction of the light source (e.g., “LP with good projection” meaning they correctly point to the light source direction, indicating some spatial localization of light).
5. **No Light Perception (NLP):** If the patient cannot even perceive a bright light shone directly into the eye, record “*NLP*” (no light perception). This

denotes total absence of vision in that eye. An eye with NLP is functionally blind.

For example, a medical record might state “VA (OD): CF @ 1m; VA (OS): HM @ face; VA (OU): CF @ 2m” etc., giving a sense of what the patient can see. Note that CF and HM are *approximate* and can vary with examiner technique (size of fingers, hand movement speed), so they are less standardized. New low vision techniques or specific low vision charts (like the Berkeley Rudimentary Vision Test) can quantify these levels more consistently, but CF/HM/LP remain common notations in practice for very poor vision.

Visual Acuity in Children and Infants

Testing visual acuity in children, especially young or pre-verbal children, requires different methods and an understanding of normal visual development. Children cannot always cooperate with a standard letter chart, so examiners use specialized charts or behavioral observations. Additionally, an infant’s visual system is still maturing, so “normal” acuity for a newborn is much lower than for an older child or adult.

- **At birth (0–1 month)**

- ✓ Very blurry vision ($\approx 20/400$ or worse).
- ✓ Brief fixation at 20–30 cm; blinks to bright light.
- ✓ Occasional horizontal tracking; early eye contact begins.

- **6–8 weeks**

- ✓ Consistent eye contact.
- ✓ Tracks horizontally, vertically, circularly.
- ✓ Social smile to familiar faces.

- **3–4 months**

- ✓ Smoother binocular tracking; better focus.
- ✓ Looks at own hands; reaches toward seen objects.
- ✓ Color vision near adult levels; recognizes familiar faces across a room.

- **6 months**

- ✓ Marked acuity improvement ($\approx 6/15$ – $6/18$ on some tests).
- ✓ Depth perception (stereopsis) is evident.
- ✓ Recognizes people/toys at distance; tracks fast-moving/rolling objects.

- **7–10 months**

- ✓ Notices small objects; develops object permanence.
- ✓ Vision guides crawling and navigation.
- ✓ Reacts to parents entering from across the room.

- **11–12 months**

- ✓ Vision approaching adult function (often $\approx 6/9$ / $20/30$).
- ✓ Looks through windows; recognizes people/animals in pictures.
- ✓ Imitates actions by watching others.

- **Toddlers (1–3 years)**

- ✓ Refines near/far focus; good hand–eye coordination.
- ✓ Names/matches shapes & colors (by ~ 2 – 3 yrs).
- ✓ By ~ 3 yrs: VA often $6/6$ – $6/7.5$ ($20/20$ – $20/25$) on cooperative testing.

- **Preschool (4–5 years)**

- ✓ Visual skills essentially mature; ready for detailed tasks (letters/numbers).
- ✓ VA typically $\approx 6/6$ ($20/20$); deviations warrant screening for amblyopia/refractive error.

HOME WORK

1. Using the formula $X = R \cdot \theta$ for calculating symbol size on eye charts:
 - a) What does each variable represent?
 - b) If $R = 6$ meters, calculate X
2. Define visual acuity (VA) and explain why it is considered a *subjective* test in clinical practice.
3. What does the Snellen fraction represent? Explain the meaning of both the numerator and the denominator.
4. A patient has $VA = 6/18$. What does this indicate about their visual ability compared to a person with normal vision?
5. Convert the following acuities between metric and US notation:
 - a) $6/12 \rightarrow ?$
 - b) $20/40 \rightarrow ?$
6. List the four levels of visual impairment as classified by the World Health Organization (WHO) and give the corresponding VA ranges.
7. Explain the concept of the Minimum Angle of Resolution (MAR) and its relation to the 6/6 (20/20) standard.
8. What is an optotype, and how is it designed to test a specific visual angle?
9. Differentiate between Distance Visual Acuity (DVA) and Near Visual Acuity (NVA).
10. Describe how to test distance visual acuity in an adult, listing the main procedural steps from preparation to recording.
11. If a patient cannot see the largest letter on the chart, what sequence of alternative tests is performed to assess very low vision?