CLASS 10 SCIENCE NOTES

Chapter: The Human Eye and the Colorful World

Comprehensive study material based on NCERT & Lakhmir Singh • Physics

1. The Human Eye

The human eye is one of the most valuable and sensitive optical sensory organs. It enables us to see the colorful world around us. It acts like a natural camera, forming a real, inverted image of objects on a light-sensitive screen called the **retina**.

Structure & Main Parts of the Human Eye

- **Cornea:** The front transparent, spherical membrane covering the eyeball. Most of the refraction for the light rays entering the eye occurs at the outer surface of the cornea.
- **Iris:** A dark, muscular diaphragm located behind the cornea that controls the size of the pupil and gives the eye its distinctive color (brown, blue, black, green).
- **Pupil:** The aperture/hole in the center of the iris through which light enters the eye. The iris regulates the amount of light entering by adjusting the pupil size:
  - In bright light, pupil contracts (becomes smaller).
  - In dim light, pupil dilates (becomes larger).
- **Eye Lens:** A convex lens made of a transparent, soft, and flexible jelly-like material (proteins). Its focal length can be modified by the ciliary muscles to focus objects at varying distances onto the retina.
- **Ciliary Muscles:** Muscles holding the eye lens in position. They modify the curvature and focal length of the eye lens to facilitate accommodation.
- **Retina:** The light-sensitive inner back surface of the eye acting as a screen. It contains millions of photoreceptor cells:
  - **Rods:** Sensitive to the intensity of light (dim light vision).
  - **Cones:** Sensitive to colors and function in bright light.
- **Yellow Spot (Fovea Centralis):** A small region at the center of the retina having maximum concentration of cones, providing the sharpest optical vision.
- **Blind Spot:** The region where the optic nerve leaves the eye for the brain. It lacks rod and cone cells, making it completely insensitive to light (no image is formed here).
- **Optic Nerve:** Transmits electrical signals produced by the photoreceptors from the retina to the visual cortex of the brain.
- **Humors:**
  - **Aqueous Humor:** Clear fluid filling the space between cornea and eye lens; maintains intraocular pressure and nourishes the cornea.
  - **Vitreous Humor:** Transparent gel filling the space between lens and retina; maintains the spherical shape of the eyeball.

📌 **Key Structural Diagram Pathway (For Board Exams):**
Light Rays → Cornea → Aqueous Humor → Pupil → Convex Eye Lens → Vitreous Humor → Retina (Real & Inverted Image) → Optic Nerve → Brain (Interpretation as Upright).

2. Power of Accommodation

The ability of the eye lens to adjust its focal length using ciliary muscles so as to clearly focus images of objects at varying distances onto the retina is called **Accommodation**.

Working Mechanism of Ciliary Muscles

Parameter	Viewing Distant Objects (Far Vision)	Viewing Nearby Objects (Near Vision)
Ciliary Muscles	Relaxed	Contracted
Eye Lens Shape	Thin (less convex)	Thick (more convex)
Focal Length (f)	Increases (Maximum)	Decreases (Minimum)
Converging Power	Decreases	Increases

Limits of Vision

- **Near Point (Least Distance of Distinct Vision - LDDV):** The minimum distance at which an object can be seen clearly without strain. For a normal young adult eye, $d = 25 ext\{ cm\}$.
- **Far Point:** The farthest distance up to which the eye can see objects clearly. For a normal eye, the far point is at **Infinity (∞)**.
- **Range of Vision:** The distance between the Near Point and the Far Point, i.e., from **25 cm to Infinity**.

> **Why do we have two eyes instead of one?**
>
> 1. **Wider Field of View:** A single eye has a horizontal field of view of about 150°, whereas two eyes give a field of view of about 180°.
> 2. **Three-Dimensional (Stereoscopic) Vision:** Because our eyes are separated by a few centimeters, each eye sees a slightly different image. The brain combines these two images to provide depth perception (3D vision).

3. Defects of Vision and Their Correction

When the eye loses its power of accommodation or structural shape, images are not focused properly on the retina, resulting in blurred vision.

1. Myopia (Near-Sightedness)

- **Description:** A person can see nearby objects clearly but cannot see distant objects distinctly. The far point of a myopic eye is less than infinity.
- **Image Formation:** Image of a distant object is formed **in front of the retina** (rather than on it).
- **Causes:**
  1. Excessive curvature of the eye lens (lens becomes too thick / high converging power).
  2. Elongation of the eyeball.
- **Correction:** Corrected using a **Concave Lens (Diverging Lens)** of suitable focal length / power. The concave lens diverges incoming parallel rays so that they appear to originate from the eye's virtual far point.

Focal Length Formula for Myopia Correction:

Using lens formula with u = -\infty and v = -x (where x is the far point distance):

rac{1}{f} = rac{1}{v} - rac{1}{u} \implies rac{1}{f} = rac{1}{-x} - rac{1}{-\infty} \implies f = -x

Power required: *P = rac{1}{f(ext{in m})}* (Always negative).

2. Hypermetropia (Far-Sightedness)

- **Description:** A person can see distant objects clearly but cannot see nearby objects distinctly. The near point of a hypermetropic eye is farther than 25 cm.
- **Image Formation:** Image of a nearby object (at 25 cm) is formed **behind the retina**.
- **Causes:**
  1. Focal length of the eye lens is too long (lens is too thin / low converging power).
  2. Eyeball has become too small (shortened).
- **Correction:** Corrected using a **Convex Lens (Converging Lens)** of suitable power. It creates additional convergence to bring the focus back onto the retina.

Focal Length Formula for Hypermetropia Correction:

Using lens formula with *u = -d = -25 ext{ cm}* and *v = -d'* (where *d'* is the defective near point):

rac{1}{f} = rac{1}{-d'} - rac{1}{-25} = rac{1}{25} - rac{1}{d'}

Power required: Always positive.

3. Presbyopia (Old Age Far-Sightedness)

- **Description:** The gradual weakening of accommodation power due to aging, making it difficult to read or see nearby objects comfortably.
- **Causes:** Gradual weakening of ciliary muscles and diminishing flexibility of the eye lens.
- **Correction:** Corrected using convex lenses for reading. If a person suffers from both myopia and hypermetropia, **Bifocal Lenses** are used:
  - Upper portion = Concave lens (for distant vision).
  - Lower portion = Convex lens (for reading/near vision).

4. Cataract

A condition in old age where the crystalline lens of the eye becomes cloudy or opaque due to protein buildup, leading to partial or complete loss of vision. It cannot be corrected by spectacle lenses; it requires **cataract surgery** (replacing the cloudy lens with an artificial Intraocular Lens - IOL).

4. Refraction of Light Through a Glass Prism

A triangular glass prism is a transparent optical medium bounded by two triangular bases and three rectangular lateral surfaces inclined at an angle called the **Angle of Prism (A)**.

📌 **Key Angles in Prism Refraction:**

- **Incident Ray:** Light ray entering the prism surface.
- **Refracted Ray:** Light ray bending inside the glass prism (bends towards the normal as light enters glass from air).
- **Emergent Ray:** Light ray coming out into air (bends away from the normal).
- **Angle of Incidence (i):** Angle between incident ray and normal.
- **Angle of Emergence (e):** Angle between emergent ray and normal at the second surface.
- **Angle of Deviation (D or δ):** The angle between the produced direction of the incident ray and the emergent ray.

Prism Formula Relation:
$A + D = i + e$
Where A = Angle of Prism, D = Angle of Deviation, i = Angle of Incidence, e = Angle of Emergence.

5. Dispersion of White Light by a Glass Prism

The phenomenon of splitting of white light into its constituent component colors upon passing through a transparent medium (like a glass prism) is called **Dispersion of Light**.

- **Spectrum:** The band of seven colored components obtained on a screen when white light splits. The sequence of colors is **VIBGYOR** (Violet, Indigo, Blue, Green, Yellow, Orange, Red).
- **Cause of Dispersion:** Different colors (wavelengths) of light travel at the same speed in vacuum/air, but at *different speeds in a refractive medium like glass.*
  - **Red light:** Longest wavelength (***lambda***), highest speed in glass → suffers **least deviation** (bends the least).
  - **Violet light:** Shortest wavelength (***lambda***), lowest speed in glass → suffers **maximum deviation** (bends the most).

Recombination of White Light (Newton's Experiment)

Sir Isaac Newton demonstrated that white light is made of seven colors. He placed two identical glass prisms, one in an upright position and the second in an **inverted position** relative to the first.

- The first prism disperses white light into seven spectrum colors.
- The second inverted prism recombines all seven colors back into a single beam of **white light** emerging from the other side.

6. Natural Phenomena Caused by Atmospheric & Dispersion Effects

1. Formation of a Rainbow

A rainbow is a natural spectrum appearing in the sky after rain. It is caused by the dispersion of sunlight by tiny spherical water droplets suspended in the atmosphere, acting like small glass prisms.

Three Sequential Optical Processes in Rainbow Formation:

1. **Refraction and Dispersion:** As sunlight enters a raindrop, it refracts and splits into seven colors.
2. **Internal Reflection:** The dispersed light rays strike the inner back surface of the water drop and undergo total/internal reflection.
3. **Refraction:** As light rays exit the droplet back into air, they undergo refraction again and reach the observer's eye.

Condition: The sun must be behind the observer to view a rainbow.

2. Atmospheric Refraction

The refraction of light caused by Earth's atmosphere due to varying optical densities of air layers at different altitudes and temperatures is called **Atmospheric Refraction**.

Hotter air is less dense (optically rarer) and has a lower refractive index, while cooler air is denser (optically denser) with a higher refractive index.

Key Applications of Atmospheric Refraction:

1. **Twinkling of Stars:**
   Stars act as distant point-sized sources of light. As starlight passes through continuously changing atmospheric layers, its path bends repeatedly. The continuous variation in atmospheric density alters the amount of light entering the eye, causing the star to appear brighter and dimmer continuously (twinkling effect).
2. **Why Planets Do Not Twinkle:**
   Planets are much closer to Earth and act as *extended sources of light* (a collection of numerous point sources). The brightness variations from individual point sources average out to zero, neutralizing the flickering effect.
3. **Advanced Sunrise and Delayed Sunset:**
   The Sun is visible to us about **2 minutes before actual sunrise** and **2 minutes after actual sunset** because of atmospheric refraction.
   - When the Sun is just below the horizon, light rays traveling from rarer space to denser air bend downwards towards the observer.
   - This causes the apparent position of the Sun to appear raised above the horizon. Total temporal difference in daylight duration = $2 + 2 = 4 \text{ minutes}$.

7. Scattering of Light

Scattering is the phenomenon in which light is absorbed by microscopic particles (atoms, molecules, dust, water drops) and then re-radiated in all directions.

Rayleigh's Law of Scattering

The intensity of scattered light (I) is inversely proportional to the fourth power of its wavelength (λ), provided the scattering particles are smaller than the wavelength of light:

$$I \propto \frac{1}{\lambda^4}$$

Consequence: Shorter wavelengths (blue/violet) are scattered much more intensely than longer wavelengths (red/orange).

1. Tyndall Effect

When a beam of light passes through a colloidal solution containing fine suspended particles, the path of the light beam becomes visible due to the scattering of light by the particles. Examples:

- Sunlight passing through a dense canopy of a canopy/forest where mist droplets scatter light.
- Light beam entering a smoke-filled room through a small hole.

2. Why is the Color of the Clear Sky Blue?

Molecules of air (N_2, O_2) in the upper atmosphere have sizes smaller than the wavelength of visible light. When sunlight passes through the atmosphere, these fine particles scatter blue light (shorter wavelength) much more strongly than red light (longer wavelength). This scattered blue light enters our eyes, giving the sky its blue appearance.

> **Note for Astronauts:** At very high altitudes or in space (where there is no atmosphere to scatter light), the sky appears **dark/black**, and stars are visible during the day.

3. Color of the Sun at Sunrise and Sunset

- At sunrise and sunset, the Sun is near the horizon. Light rays travel a **longer distance through thicker layers of atmosphere**.
- Most of the shorter blue and violet wavelengths are scattered away before reaching our eyes.
- Only the longer wavelengths (red and orange light) pass straight through to reach our eyes. Hence, the Sun and surrounding sky appear **reddish**.
- At noon, the Sun is directly overhead; light travels a shorter distance, experiencing minimal scattering, so the Sun appears white.

4. Why Danger Signal Lights are Red

Red light has the longest wavelength in the visible spectrum. According to Rayleigh's law, red light is least scattered by fog, smoke, or dust particles. Thus, it can be seen clearly from the maximum distance without intensity loss.

8. Chapter Summary & Quick Revision Table

Phenomenon / Effect	Primary Optical Principle Involved	Key Cause / Reason
Accommodation of Eye	Lens Focal Length Adjustment	Action of Ciliary Muscles
Myopia Correction	Divergence by Concave Lens	Elongated eyeball / High lens power
Hypermetropia Correction	Convergence by Convex Lens	Shortened eyeball / Low lens power
Spectrum / Rainbow	Dispersion & Total Internal Reflection	Speed difference of colors in water/glass
Twinkling of Stars	Atmospheric Refraction	Fluctuating atmospheric density layers
Advance Sunrise (2 min)	Atmospheric Refraction	Bending of light across atmospheric density gradient
Blue Sky & Red Sunset	Tyndall / Rayleigh Scattering	***I \propto 1/\lambda^4*** (Wavelength dependent scattering)