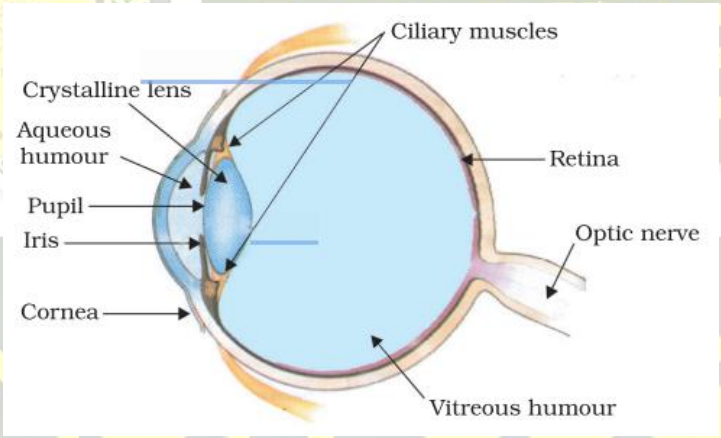
The Human Eye and the Colourful World

This chapter explores how the human eye uses light and lenses to enable vision, and how lenses in spectacles correct vision defects. It also delves into natural optical phenomena, like rainbows and the blue color of the sky.

THE HUMAN EYE

- **The Eye's Importance:**
  - The human eye is a crucial sense organ that allows us to perceive the world and its colors.
  - While other senses help identify objects, the eye is unique in enabling color perception.
- **Structure and Function:**
  - **Camera Analogy:** The eye functions like a camera, with a lens system focusing an image onto a light-sensitive screen (retina).
  - **Cornea:** The transparent outer layer of the eye where most of the light refraction occurs.
  - **Crystalline Lens:** Fine-tunes the focus for objects at varying distances.
  - **Iris and Pupil:** The iris controls the pupil's size, regulating the amount of light entering the eye.
  - **Retina:** Contains light-sensitive cells that generate electrical signals when illuminated.
  - **Optic Nerves:** Transmit signals from the retina to the brain for interpretation.
  - **Brain Processing:** The brain processes the signals to create our visual perception of objects.



The human eye

Power of Accommodation

- **Eye Lens:**
  - Made of a flexible, jelly-like material.
  - Curvature can be adjusted by ciliary muscles.
- **Focusing:**

    - **Relaxed Muscles:** Lens thins, focal length increases, allowing clear vision of distant objects.
    - **Contracted Muscles:** Lens thickens, focal length decreases, enabling clear vision of nearby objects.
- **Accommodation:**
    - The eye's ability to change its focal length for focusing on objects at different distances.
- **Near Point:**
    - The closest distance at which an object can be seen clearly without strain (about 25 cm for a young adult).
- **Far Point:**
    - The farthest distance at which an object can be seen clearly (infinity for a normal eye).
- **Cataract:**
    - A condition where the eye lens becomes cloudy, causing vision loss.
    - Treatable with surgery.

Defects of Vision and Their Correction

- **Refractive Defects:**
    - Occur when the eye loses its power of accommodation.
    - Cause blurred vision.
- **Types of Refractive Defects:**
    - **Myopia (Near-sightedness):**
        - Difficulty seeing distant objects.
        - Image forms in front of the retina.
        - Caused by excessive lens curvature or an elongated eyeball.
        - Corrected with concave lenses.
    - **Hypermetropia (Far-sightedness):**
        - Difficulty seeing nearby objects.
        - Image forms behind the retina.
        - Caused by an insufficiently curved lens or a short eyeball.
        - Corrected with convex lenses.
    - **Presbyopia:**
        - Age-related decline in accommodation ability.
        - Difficulty seeing nearby objects.
        - Caused by weakening ciliary muscles and reduced lens flexibility.
        - Often corrected with bifocal lenses (concave for distance vision, convex for near vision).
- **Correction Methods:**
    - Eyeglasses.
    - Contact lenses.
    - Surgical interventions.

(a) Far point of a myopic eye

(b) Myopic Eye

(c) Correction for myopia

Refraction of Light Through a Prism

- **Difference from Glass Slab:**
  - Unlike a glass slab where the emergent ray is parallel to the incident ray, a prism bends the emergent ray at an angle.
- **Prism Structure:**
  - Two triangular bases.
  - Three rectangular lateral surfaces inclined to each other.
  - Angle of the prism: the angle between two lateral faces.
- **Refraction Process:**
  - **First Surface:** Light enters from air to glass, bending towards the normal.
  - **Second Surface:** Light exits from glass to air, bending away from the normal.
- **Angle of Deviation:**
  - The angle between the incident ray and the emergent ray.
  - Caused by the prism's shape.
- **Activity:**
  - Observe the refraction of light through a triangular glass prism.
  - Identify the incident ray, refracted ray, and emergent ray.
  - Compare the angles of incidence and refraction at each surface.
  - Mark and measure the angle of deviation.

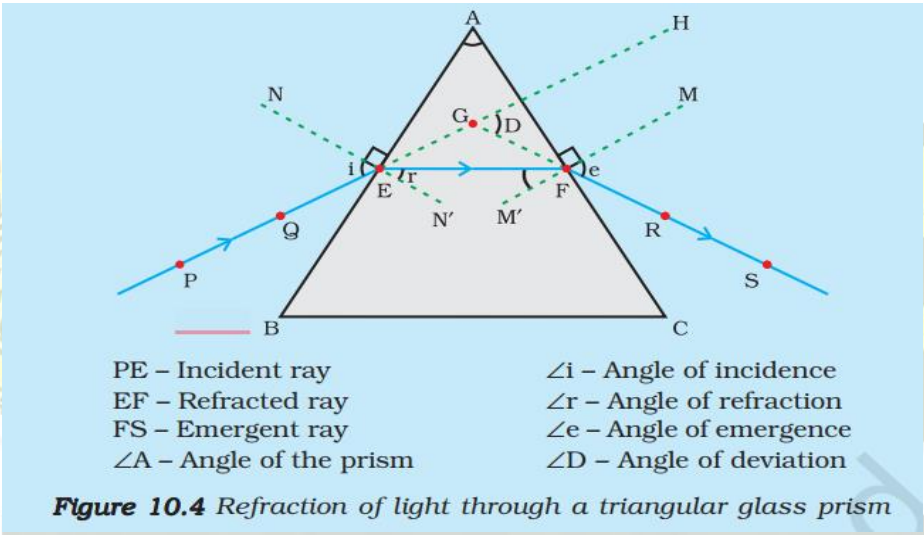
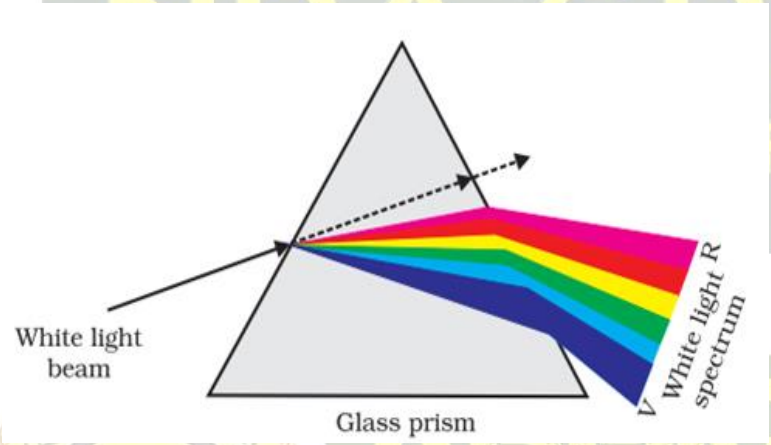
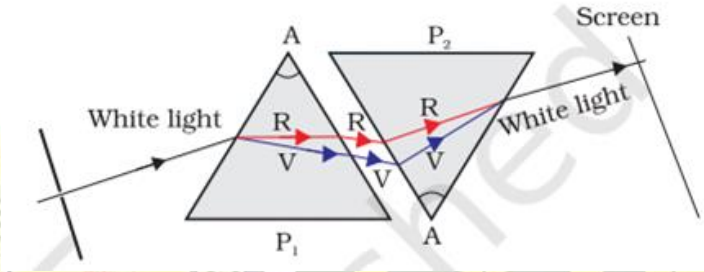


Figure 10.4 *Refraction of light through a triangular glass prism*

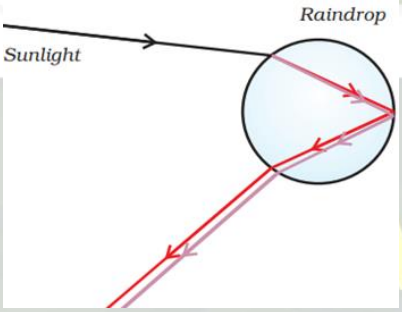
Dispersion of White Light by a Glass Prism



- **Rainbow Colors:**
  - Rainbows demonstrate the phenomenon of white light splitting into different colors.
- **Prism Effect:**
  - A prism splits white light into a band of colors (spectrum).
  - The sequence of colors is VIBGYOR (Violet, Indigo, Blue, Green, Yellow, Orange, Red).
- **Dispersion:**
  - The process of splitting light into its component colors.
  - Occurs because different colors of light bend at different angles when passing through a prism.
  - Red light bends the least, violet light bends the most.
- **Newton's Experiment:**
  - Newton used a prism to obtain the spectrum of sunlight.
  - He showed that white light is composed of seven colors by recombining the spectrum using a second inverted prism.
- **White Light:**
  - Any light that produces a spectrum similar to sunlight is considered white light.



- **Rainbow Formation:**
  - Rainbows are natural spectra formed by the dispersion of sunlight by water droplets in the atmosphere.
  - Water droplets act like small prisms, refracting and dispersing sunlight.
  - Internal reflection within the droplets contributes to the rainbow's appearance.
- **Other Rainbow Observations:**
  - Rainbows can also be seen in waterfalls or fountains when sunlight passes through them.
  - Rainbows always appear in the direction opposite to the Sun.

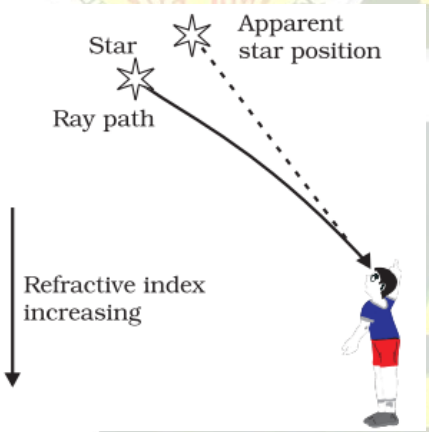


Rainbow formation

Atmospheric Refraction

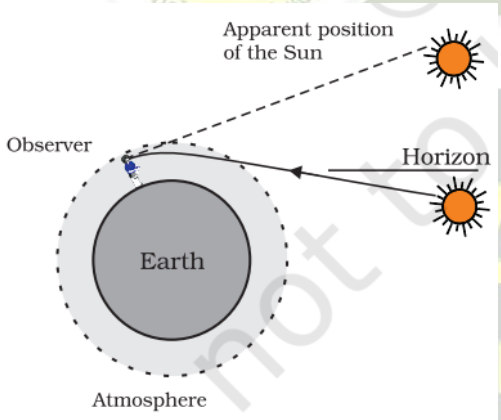
- **What it is:** The bending of light as it passes through the Earth's atmosphere.
- **Causes:**
  - Variations in air temperature and density.
  - Hot air is less dense and has a lower refractive index than cooler air.
- **Effects:**

- **Wavering of Objects:** Seen above fires or radiators due to the turbulent hot air.
- **Twinkling of Stars:**
  - Starlight bends as it passes through the atmosphere.
  - The apparent position of stars changes slightly due to varying atmospheric conditions.
  - Stars appear to twinkle because they are point sources of light, and the amount of light reaching our eyes fluctuates.



Apparent star position due to atmospheric refraction

- **Planets Don't Twinkle:**
  - Planets are closer and appear as extended sources of light.
  - Variations in light from different points on the planet average out, preventing twinkling.
- **Advanced Sunrise and Delayed Sunset:**
  - The Sun appears about 2 minutes earlier and sets about 2 minutes later than its actual position due to atmospheric refraction.
  - This also causes the apparent flattening of the Sun's disc at sunrise and sunset.



Atmospheric refraction effects at sunrise and sunset

Scattering of Light

- **What it is:** The process where light is redirected in different directions when it interacts with particles in a medium.

- **Examples in Nature:**
  - Blue color of the sky.
  - Reddening of the Sun at sunrise and sunset.
  - Color of water in the deep sea.
- **Tyndall Effect:**
  - Scattering of light by colloidal particles (like smoke or tiny water droplets) makes the path of a light beam visible.
  - Examples: Sunlight entering a smoky room, sunlight passing through a dense forest canopy.
- **Color Dependence:**
  - The color of scattered light depends on the size of the scattering particles.
  - Very small particles scatter blue light (shorter wavelength).
  - Larger particles scatter longer wavelengths, which can appear white.
- **Why the Sky is Blue:**
  - Air molecules are smaller than the wavelength of visible light.
  - They scatter blue light more strongly than red light.
  - This scattered blue light is what we see as the blue sky.