

# Optics

These notes are your ultimate revision weapon to revise Optics. We've distilled years of previous exam questions (PYQs) into one powerful, concise resource. Everything you need to know, nothing you don't.

- **PYQs, Decoded:** All key concepts from past exams, organized and simplified.
- **Revise in Record Time:** Short, precise, and designed for last-minute review.
- **Focus on What Matters:** Master high-probability topics and boost your confidence.

## 1. The Electromagnetic Spectrum & Light Ranges

- **Solar Radiation Reaching Earth:**
  - Wavelength range: Approximately 100 nm to  $10^6$  nm.
- **Ultraviolet (UV) Radiation:** Wavelengths below 400 nm.
  - **UV-A:** 320-400 nm (causes tanning).
  - **UV-B:** 280-320 nm (can lead to skin cancer).
  - **UV-C:** Below 280 nm (most dangerous, but largely absorbed by atmospheric oxygen).
- **Visible Light:**
  - Wavelength range: Approximately 400-700 nm (or 380-750 nm, 390-780 nm, 3900-7600 Å).
  - Human eyes can typically perceive light from about 380 nm to 750 nm.
  - The human eye is most sensitive to yellowish-green light (~555 nm or 530-570 nm).
    - *Incorrect statement:* "The human eye is most sensitive to red colour."
- **Infrared (IR) Radiation:** Wavelengths above 700 nm.

## 2. Fundamental Properties of Light

- **Nature of Light:** Exhibits wave-particle duality (behaves like both a wave and a particle).
- **Photon Energy:**
  - Inversely proportional to its wavelength.
  - Shorter wavelength = Higher energy.
  - Among given options, 200-280 nm radiation has the highest energy per quantum.
- **Speed (Velocity) of Light:**
  - In a vacuum:  $3 \times 10^8$  m/s (maximum possible speed for energy/information).
  - In different media: Light travels slower than in a vacuum. Speed is minimum in glass.
  - Speed in air depends on temperature, pressure, and humidity.
  - Sunlight takes about 8 to 8.5 minutes to travel from the Sun to Earth.
- **Rectilinear Propagation:** Light travels in a straight line because its wavelength is very small.

## 3. Behavior of Light: Reflection, Refraction, and Scattering

### A. Refraction

- **Definition:** The bending of light when it passes from one medium to another.
- **Changes during Refraction:**
  - **Changes:** Velocity/Speed and Wavelength.
  - **Remains Constant:** Frequency.
- **Direction of Bending:**
  - **Rarer to Denser Medium (e.g., air to glass):** Light slows down and bends **towards** the normal.
  - **Denser to Rarer Medium (e.g., glass to air):** Light speeds up and bends **away** from the normal.

- **Examples & Effects:**

- A stick dipped in water appears short and bent.
- A coin in water appears closer to a person in the air; a coin in the air appears higher to a person underwater.
- Advanced sunrise and delayed sunset occur due to atmospheric refraction.
- The sun and moon appear slightly elliptical near the horizon due to atmospheric refraction.

## **B. Total Internal Reflection (TIR)**

- **Principle & Condition:**

- Occurs when light travels from a denser medium to a rarer medium.
- The angle of incidence must be greater than the critical angle.

- **Applications:**

- **Optical Fibres:** Transmit light signals with minimal loss (very low power consumption, no radio frequency interference).
- **Endoscopes:** Medical instruments for viewing inside the body.
- **Diamond Brilliance:** Due to high refractive index and multiple TIRs.
- **Mirage:** An optical illusion caused by TIR in layers of air of different temperatures.
- **Traffic Signal Beads:** Glow brightly due to TIR.

## **C. Scattering**

- **Rayleigh Scattering:** Scattering of light by particles much smaller than its wavelength.

- Shorter wavelengths (blue, violet) are scattered much more than longer wavelengths (red, orange).

- **Atmospheric Phenomena:**

- **Blue Sky:** Due to the scattering of blue light by air molecules.
- **Red Sun at Sunrise/Sunset:** Blue light is scattered away, leaving red/orange light to reach the observer.

- **View from Space:** The sky appears black because there is no atmosphere to scatter light.

## D. Dispersion & Rainbows

- **Dispersion:** The splitting of white light into its constituent colors (VIBGYOR) by a prism.
- **Rainbow:**
  - A natural spectrum caused by reflection, refraction, and dispersion in water droplets.
  - Color sequence: Red, Orange, Yellow, Green, Blue, Indigo, Violet (VIBGYOR). Central color is green.
  - Formed in the direction opposite to the Sun. Cannot be seen at 12 noon when the sun is overhead.

## E. Interference

- **Definition:** The combination of waves leading to a new wave pattern.
- **Example:** The formation of glittering colors on a thin soap film or soap bubble.

## 4. Light and Color

- **Color of Light:**
  - Determined by its wavelength.
  - **Visible Spectrum Order (by increasing wavelength):** Violet, Indigo, Blue, Green, Yellow, Orange, Red (VIBGYOR).
- **Color of Objects:**
  - The color of an opaque object is due to the color of light it **reflects**; it absorbs other colors.
  - A white object reflects all light; a black object absorbs all light.
- **Color Mixing:**
  - **Light (Additive):** Primary colors are Red, Green, Blue (RGB). Mixing them equally produces white light.
  - **Pigments (Subtractive):** Primary colors are Cyan, Magenta, Yellow.

- **Applications:**

- **Danger/Traffic Signals (Red):** Red light is used because it has the longest wavelength and is scattered the least, allowing it to travel farthest.
- **Summer Clothing:** White/light-colored clothes are preferred as they reflect light and absorb less heat.
- **Color of Water Bodies:** The sea appears blue due to reflection of the sky and scattering by water molecules.

## 5. The Human Eye and Vision

- **Image Formation:**

- Light is focused by the lens to form a **real, inverted, and smaller** image on the **retina** (which acts like camera film).
- The brain interprets these signals and corrects the inversion.

- **Key Features:**

- **Persistence of Vision:** An image persists on the retina for about **1/16 of a second**. This is the principle behind motion pictures.
- **Least Distance of Distinct Vision (Near Point):** For a normal eye, this is **25 cm**.
- **Stereopsis (Depth Perception):** Having two eyes provides depth perception because each sees a slightly different image.
- **Ciliary Muscles:** Control the curvature (and thus focal length) of the eye lens.
  - Relaxed: Lens thin, for seeing distant objects.
  - Contracted: Lens thick, for seeing nearby objects.

- **Defects of Vision:**

- **Hypermetropia (Long-sightedness):** Can see far objects clearly, but not nearby ones. Image focuses behind the retina. Corrected with a **convex lens**.
- **Myopia (Short-sightedness):** Can see near objects clearly, but not distant ones. Corrected with a **concave lens**.

- **Eye Safety:** Viewing the sun directly, especially during an eclipse, can cause retinal burns from ultraviolet light.

- **Dark Adaptation:** The delay in seeing in a dark room is due to the reformation of Rhodopsin in rod cells and pupil dilation.

## 6. Optical Instruments and Applications

### A. Mirrors

- **Plane Mirrors:**
  - The minimum height to see a full-length image is **half the person's height**.
  - The radius of curvature is infinity.
  - Rotating the mirror by an angle  $\theta$  rotates the reflected ray by  $2\theta$ .
  - Parallel mirrors produce an infinite number of images.
- **Convex Mirrors (Curved Outwards):**
  - Always form a **virtual, erect, and diminished** image.
  - Provide a wider field of view. Used as rear-view mirrors in vehicles.
- **Concave Mirrors (Curved Inwards):**
  - Can form real or virtual images.
  - When the object is between the pole and the focus, the image is **virtual, erect, and magnified**.
  - Applications: Shaving/makeup mirrors, dentist mirrors, searchlights/headlights.

### B. Lenses

- **Lens Power:** Measured in Dioptres (D). Power (D) =  $1 / \text{Focal Length (meters)}$ .
  - Convex (converging) lenses have **positive (+) power**.
  - Concave (diverging) lenses have **negative (-) power**.
  - A sunglass typically has 0 diopters of power.
- **Lens Combinations:** A convex and concave lens of the same focal length in contact act like a plane glass sheet.
- **Air Bubble in Water:** Behaves as a divergent (concave) lens.

## C. Other Technologies

- **Holography:** A technique to create a true 3D image using interference of light.
- **CD/DVD Players:** Use a **laser beam** to read information.
- **CRT Monitors:** Use a **raster scan** method where an electron beam hits a phosphorous-coated screen.
- **CD Surface:** Rainbow colors are caused by reflection and diffraction of light from its layered structure.

## 7. Related Wave Phenomena

- **Sound & Signal Transmission:**
  - In TV broadcasts, **Frequency Modulation (FM)** is used for audio due to its wide frequency range and minimal noise.
  - Radio waves are produced by rapidly oscillating electrical currents.
- **Doppler Effect:**
  - The change in observed frequency/wavelength due to relative motion between source and observer.
  - Used by police radar to detect speeding vehicles (with radio waves).
  - A blue light source moving away from an observer would appear shifted towards longer wavelengths (e.g., yellow/red).

### Know More About Optics:

- [Optics – Old Year Questions](#)
- [Optics One Liner Questions & Answers](#)