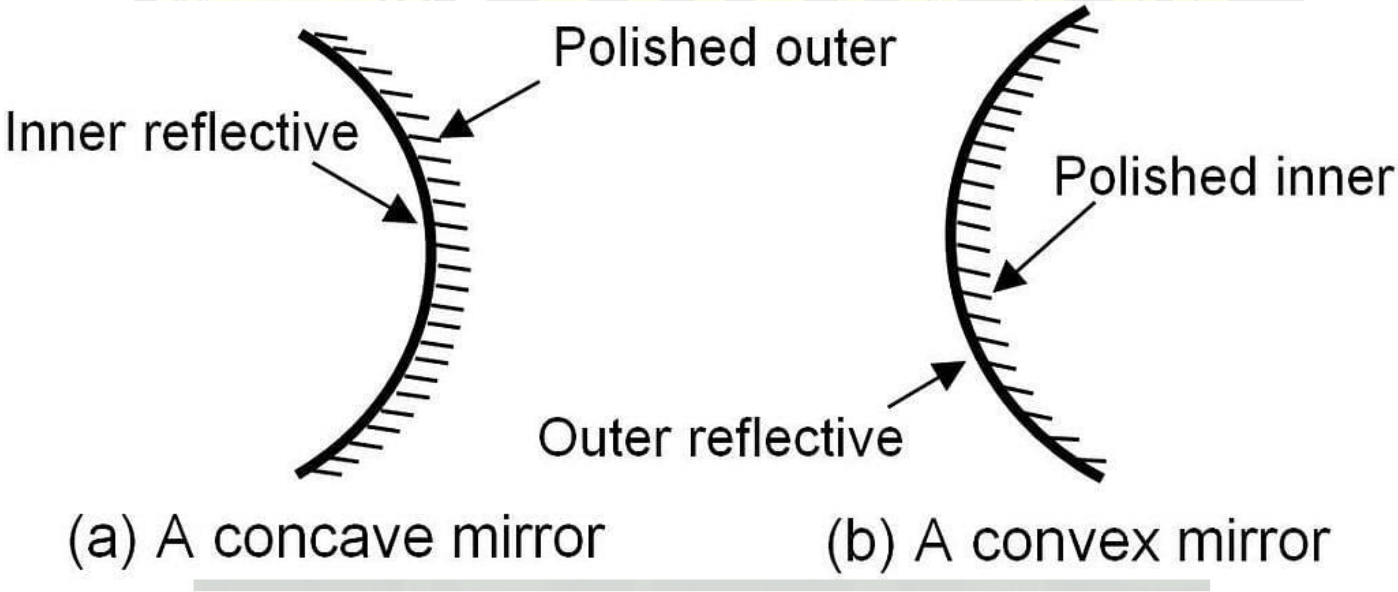
Class 14; Mirror & Lens

Types of Mirrors

Mirrors are surfaces that reflect light in such a way that an image of the object placed in front of them is formed. There are primarily two types of spherical mirrors based on the curvature of their reflecting surface: concave and convex mirrors.



1. Concave Mirror

- **Definition**: A concave mirror is a spherical mirror with its reflecting surface curved inward, resembling the inside of a sphere.
- **Uses**:
  - **Torches, Search-lights, and Headlights**: Used to produce powerful, parallel beams of light.
  - **Shaving Mirrors**: Provides a magnified reflection, useful for close-up views.
  - **Dental Mirrors**: Allows dentists to see enlarged images of teeth.
  - **Solar Furnaces**: Large concave mirrors concentrate sunlight to generate heat.
- **Image Formation**: Can form real, inverted images or virtual, erect images depending on the position of the object relative to the focal point.

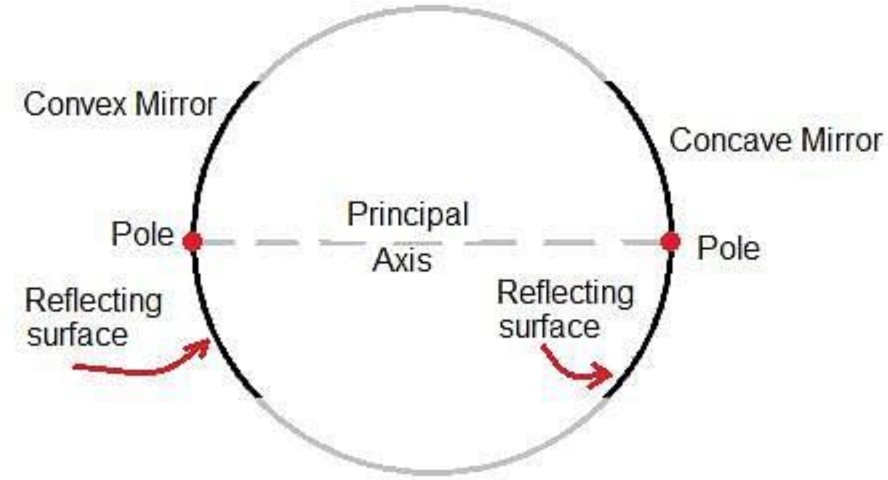
2. Convex Mirror

- **Definition**: A convex mirror has its reflecting surface curved outward, like the exterior of a sphere.
- **Uses**:
  - **Rear-view Mirrors in Vehicles**: Provide a wider field of view, allowing drivers to see more of the road behind them.
- **Image Formation**: Always forms virtual, erect, and diminished images. This property helps in giving a broad view of the area.

Other Key Terms in Spherical Mirrors:

- **Pole (P)**: The center of the mirror's surface.
- **Center of Curvature (C)**: The center of the sphere from which the mirror segment is taken.
  - Lies in front of a concave mirror.
  - Lies behind a convex mirror.
- **Radius of Curvature (R)**: The distance between the pole and the center of curvature.

- **Principal Axis**: A straight line passing through the pole and the center of curvature.

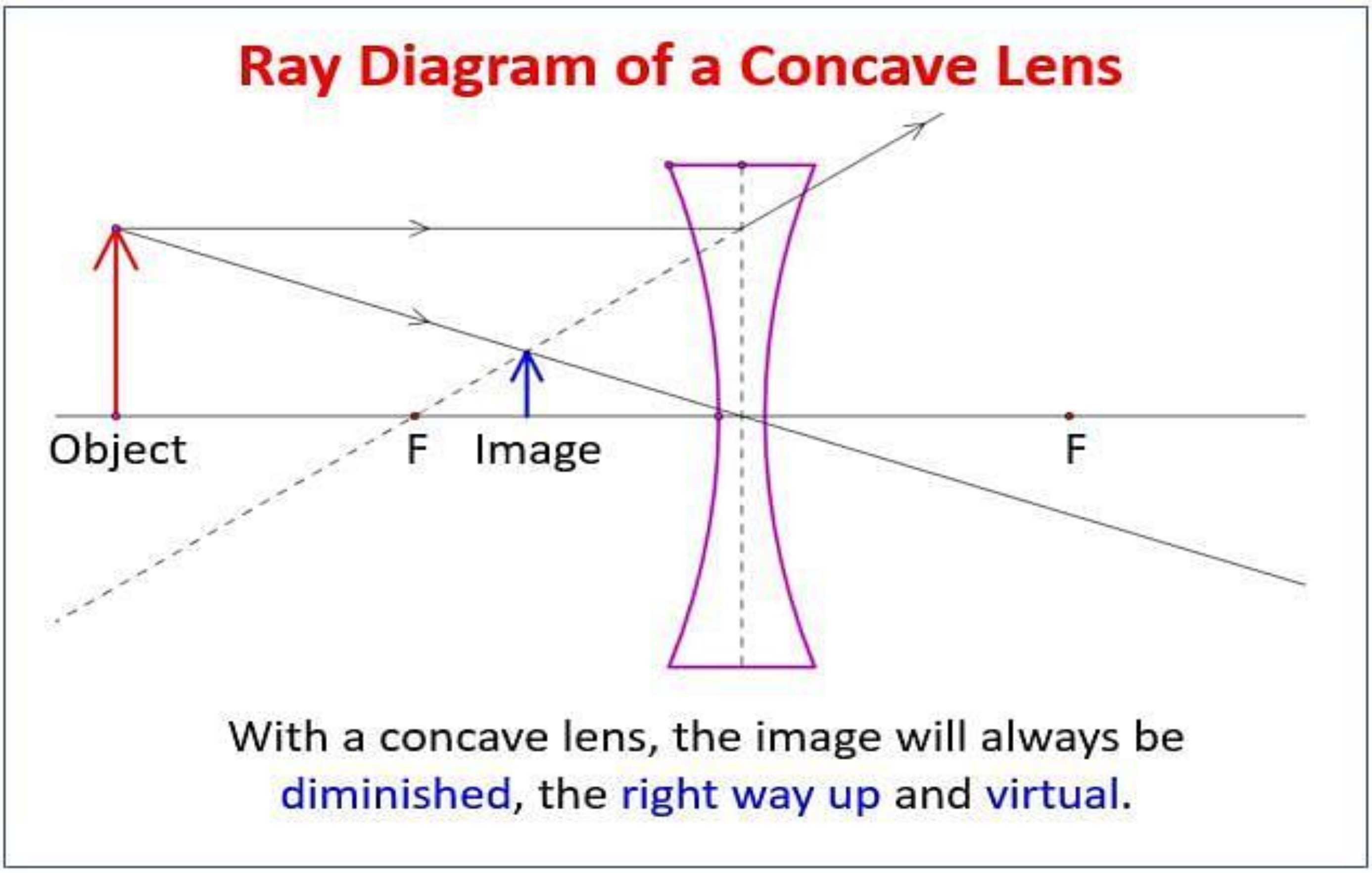


Types of Lenses

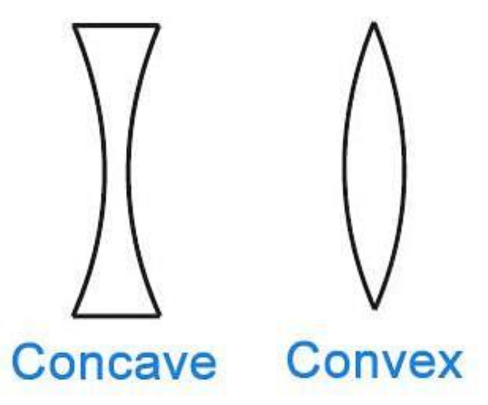
Lenses are transparent optical devices that refract light to form images. They are classified based on their shapes and the way they bend light. Here's a closer look at concave and convex lenses:

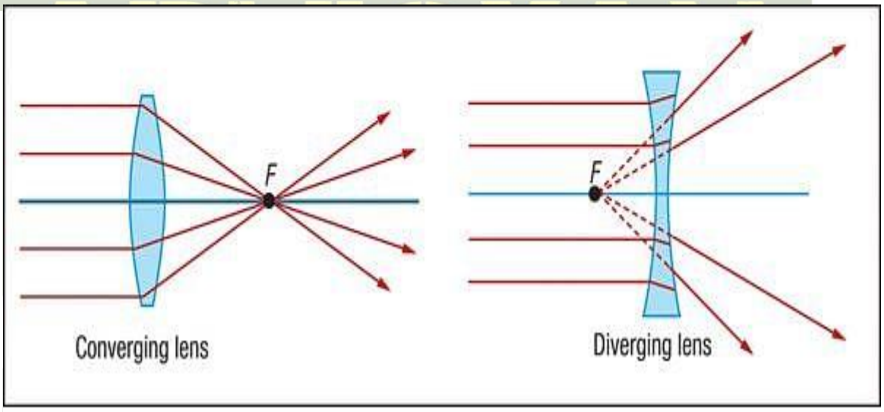
1. Concave Lenses

- **Definition**: A concave lens is thinner in the center than at the edges.
- **Properties**:
  - **Diverging Lens**: It causes light rays to spread out (diverge).
  - **Image Formation**: Always forms virtual, erect, and smaller images compared to the object.



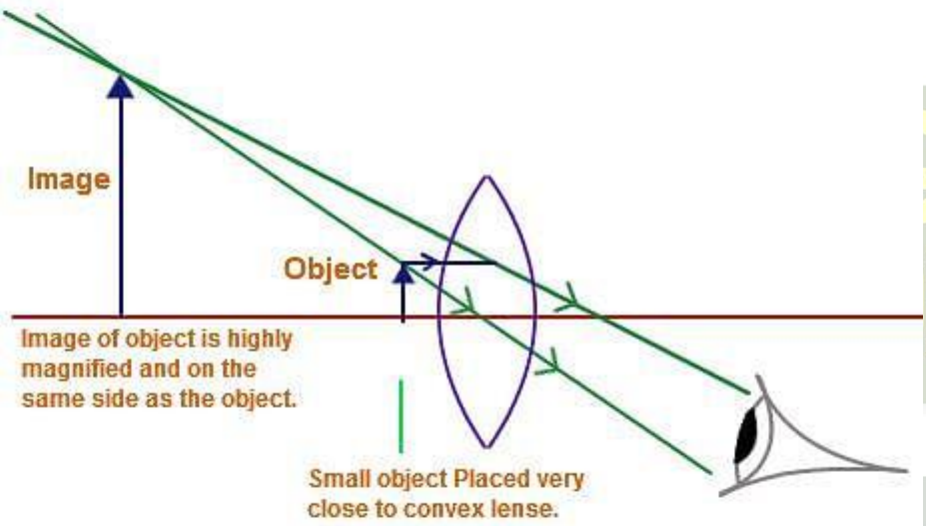
- **Uses**:
  - **Corrective Lenses**: Used in eyeglasses for people with myopia (nearsightedness).
  - **Laser Beams**: Helps to expand the beam's diameter.





2. Convex Lenses

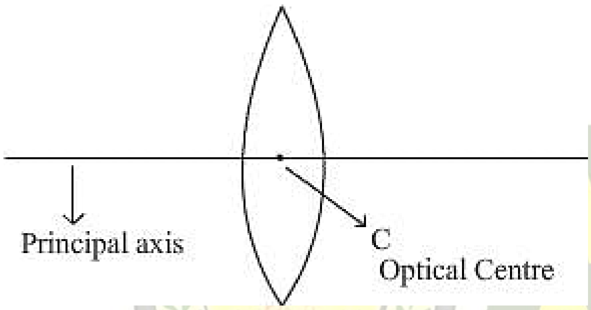
- **Definition**: A convex lens is thicker in the center than at the edges.
- **Properties**:
  - **Converging Lens**: It brings light rays together (converges) at a focal point.
  - **Image Formation**: Can form real, inverted images or virtual, erect images depending on the object's distance.



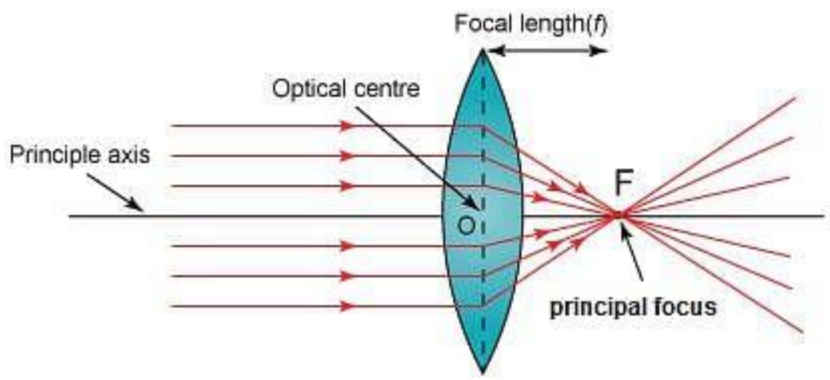
- **Uses**:
  - **Magnifying Glass**: Used to magnify objects when viewed through it.
  - **Cameras and Projectors**: Used to focus light to form images on film or screens.
  - **Corrective Lenses**: Used in glasses for people with hyperopia (farsightedness).

Other Key Terms Related to Lenses

- **Principal Axis**: A straight line passing through the centers of the two spherical surfaces forming the lens.



- **Optical Center**: The central point within the lens, equidistant from the surfaces in lenses with equal curvature.
- **Focus of a Convex Lens**: The point where parallel rays converge after passing through the lens.
- **Focal Length (f)**: The distance between the optical center and the focus. It's a crucial factor in determining the lens's power.



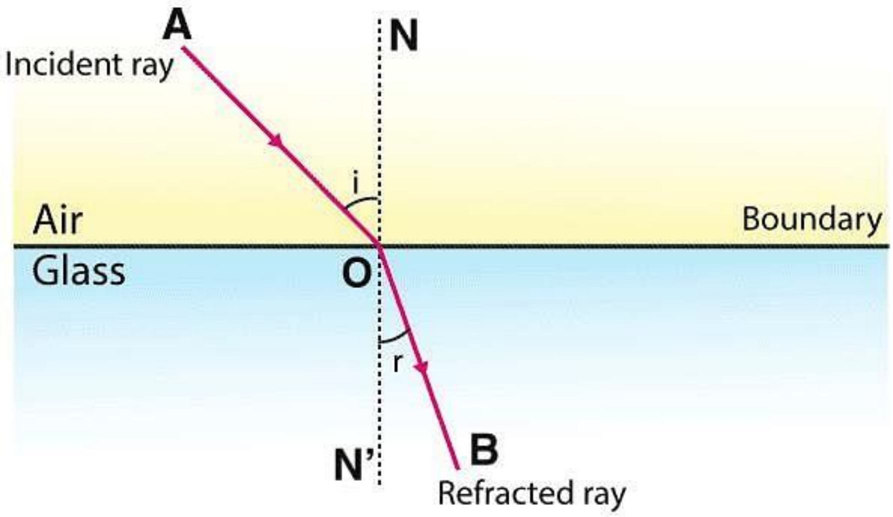
- **Power of a Lens**: It measures the lens's ability to bend light and is the reciprocal of the focal length (in meters). The unit of power is dioptre (D), where 1 D equals 1 m^{-1}.
  - **Positive Power**: Convex lenses have positive power as they converge light.
  - **Negative Power**: Concave lenses have negative power as they diverge light.

2. Refraction of Light

Refraction is the bending of light as it passes from one medium to another with a different optical density. Here's a detailed breakdown of the phenomenon:

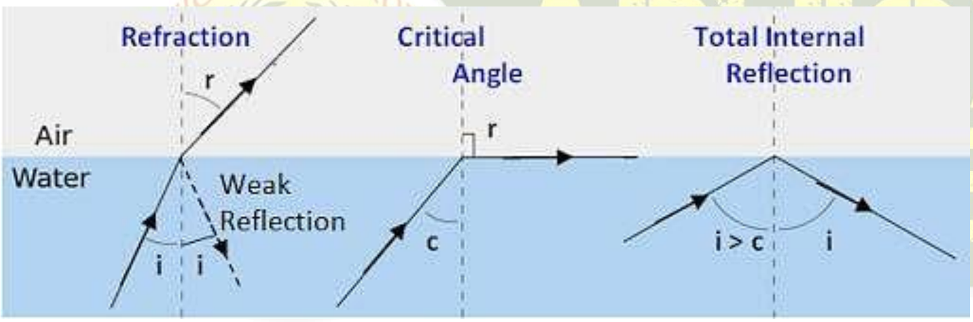
Understanding Refraction

- **Definition**: Refraction is the phenomenon where a ray of light deviates from its original path when it crosses the boundary between two different optical media. This change in direction occurs due to the change in the speed of light in different media.
- **Cause**: Light changes speed when it moves from one medium to another with different optical densities. For instance, light travels faster in air (less dense) and slower in water (denser). This change in speed causes the light ray to bend.



How Refraction Occurs

- **Optically Rare to Denser Medium**: When light travels from an optically less dense medium (like air) to a more dense medium (like water), it bends towards the normal (an imaginary line perpendicular to the surface at the point of incidence).
  - **Example**: A pencil partially submerged in water appears bent at the surface because the light rays bend as they move from water to air.
- **Optically Denser to Rare Medium**: Conversely, when light travels from a denser medium to a rarer medium, it bends away from the normal.
  - **Example**: When a light ray exits water into the air, it bends away from the normal line.
- **No Deviation**: If a ray of light hits the boundary between two media directly perpendicular (normal) to the surface, it continues in the same direction without bending.



Refractive Indices

The degree to which light is bent or refracted when entering a new medium is described by the medium's refractive index (n). The refractive index is a measure of how much the speed of light is reduced inside the medium.

- **Examples**:
  - **Diamond**: n=2.419n = 2.419n=2.419 (light slows down significantly)
  - **Glass**: n=1.523n = 1.523n=1.523
  - **Water**: n=1.33n = 1.33n=1.33

The higher the refractive index, the more the light bends towards the normal when entering that medium.

Total Internal Reflection

Total internal reflection is a special case of refraction where the light is completely reflected within a medium instead of passing through the boundary into another medium. This phenomenon can only occur under specific conditions:

- **Conditions for Total Internal Reflection**:
  - **Denser to Less Dense Medium**: The light must be in the denser medium and approach the boundary with a less dense medium.
  - **Angle of Incidence**: The angle of incidence (the angle between the incident ray and the normal) must be greater than the critical angle for the specific medium pair.
- **Critical Angle**: The minimum angle of incidence at which total internal reflection occurs. Beyond this angle, all the light is reflected back into the denser medium instead of being refracted.
  - **Example**: Fiber optics use total internal reflection to transmit light over long distances with minimal loss.

Illustration of Refraction and Total Internal Reflection

Here's a visual explanation to clarify the concepts:

1. **Refraction at Boundary**:
   - When light passes from air to water, it bends towards the normal.
   - When light passes from water to air, it bends away from the normal.
2. **Total Internal Reflection**:
   - Light inside water approaching the air boundary at an angle greater than the critical angle will reflect entirely back into the water.

3. Dispersion of Light: Dispersion of light refers to the phenomenon where a beam of white light splits into its constituent colors when it passes through a prism. This separation occurs because different colors (or wavelengths) of light bend by different amounts when passing through a medium like glass or water.

Understanding Dispersion

- **Definition**: Dispersion is the process by which a beam of white light separates into its component colors when it passes through a dispersive medium, such as a prism.
- **Cause**: Different colors of light travel at different speeds in a medium like glass. This speed difference causes each color to refract (bend) by a different amount as it exits the prism, leading to the separation of colors.

Colors of Dispersion: When white light passes through a prism, it separates into a spectrum of colors. The order of colors from the bottom to the top is:

1. **Violet**
2. **Indigo**
3. **Blue**
4. **Green**
5. **Yellow**
6. **Orange**
7. **Red**

The sequence of these colors can be remembered using the acronym **VIBGYOR**.

Mechanism of Dispersion

- **Prism Effect**: When white light enters a prism, each color in the light spectrum refracts at a slightly different angle due to varying wavelengths.
    - **Violet** light bends the most because it has the shortest wavelength and travels slowest in the glass.
    - **Red** light bends the least because it has the longest wavelength and travels fastest in the glass.
- **Emerging Spectrum**: As light exits the prism, these colors are spread out into a band, creating a visible spectrum of light.

Application of Dispersion

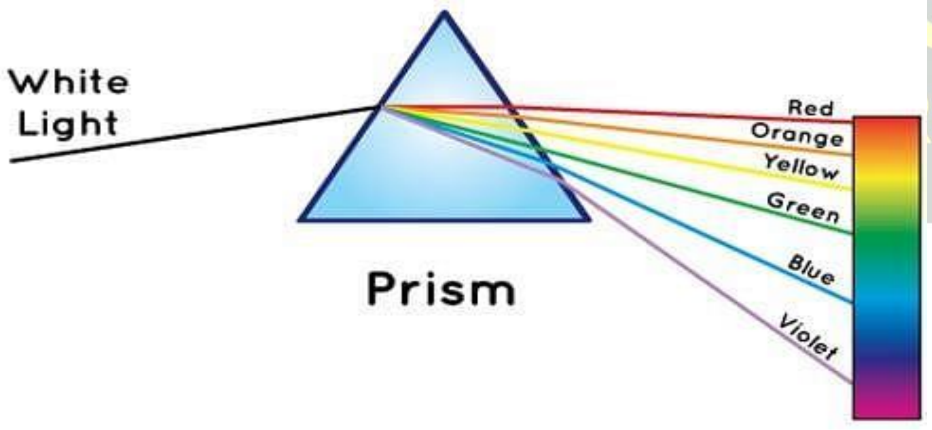
- **Rainbows**: Natural examples of dispersion are rainbows, which occur when sunlight passes through water droplets in the atmosphere, splitting into its component colors.
- **Spectroscopy**: Dispersion is used in spectroscopy to analyze the composition of light from stars and other sources by examining the spectrum of light.
- **Prism Experiments**: Dispersion is a fundamental concept demonstrated in many physics and optics experiments using prisms.

Laser Light

A laser is a powerful beam of light that has unique properties, and understanding it helps provide a contrast to dispersed light.

- **Definition**: **Laser** stands for **Light Amplification by Stimulated Emission of Radiation**. It is a device that emits light through a process of optical amplification.
- **Characteristics of Laser Light**:
    - **Monochromatic**: Laser light typically consists of one color (one wavelength), unlike white light which contains multiple colors.
    - **Coherent**: The light waves are in phase in both time and space.
    - **Directional**: Laser light is emitted in a tight, narrow beam that does not spread out significantly.
- **Applications**:
    - **Medical**: Used in surgeries and treatments, such as eye surgeries.
    - **Communications**: Used in fiber-optic communication for transmitting data over long distances.
    - **Technology**: Used in CD/DVD players, barcode scanners, and various industrial applications.

Illustration of Dispersion and Laser Light



Here’s a visual explanation to enhance understanding:

1. **Dispersion through a Prism**:
    - White light entering a prism splits into a spectrum of colors: red, orange, yellow, green, blue, indigo, and violet, displaying the dispersion effect.
2. **Laser Light Characteristics**:
    - Unlike dispersed light, a laser beam remains a single color, is highly directional, and maintains a tight beam over long distances.