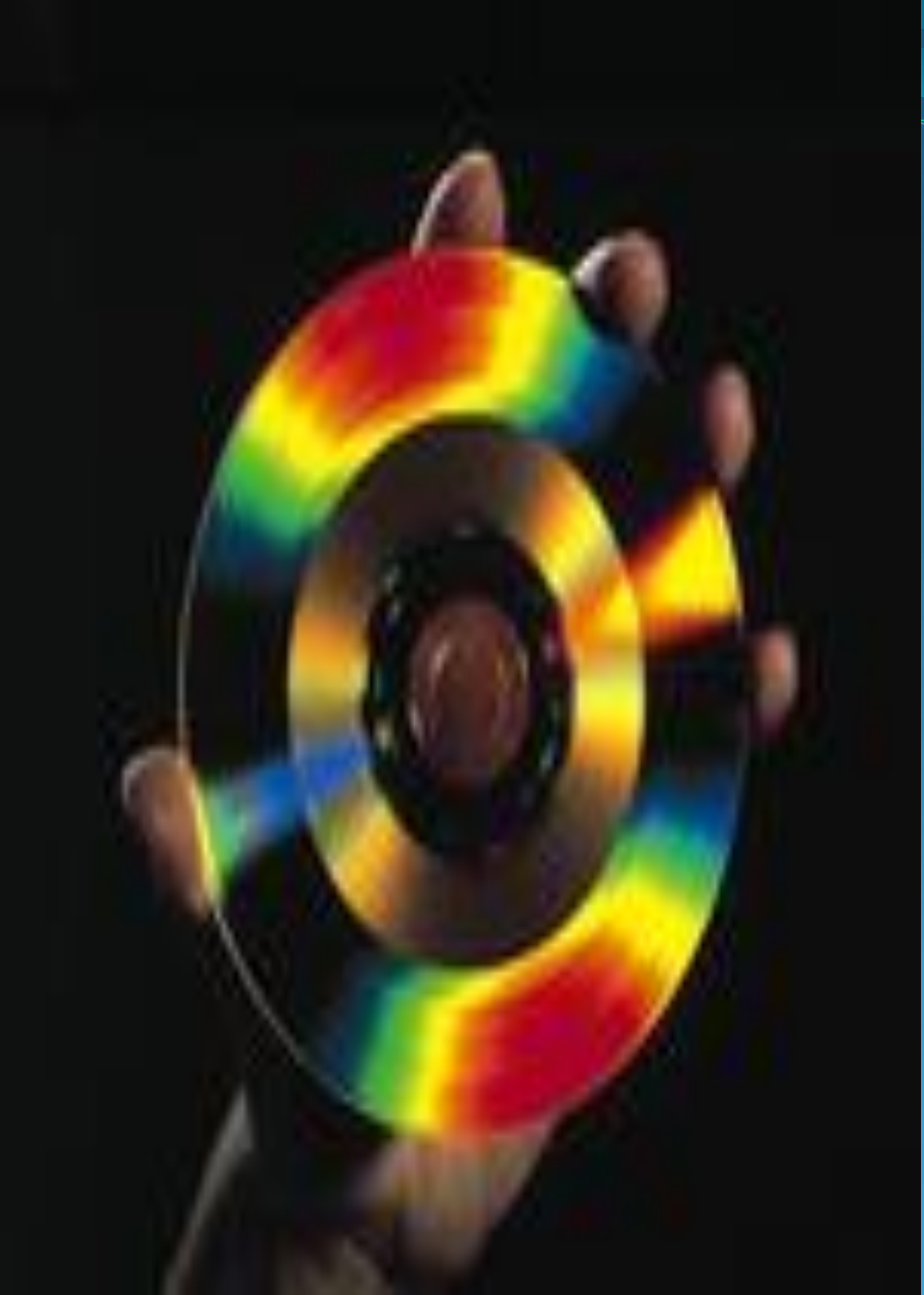


Chapter 38

Diffraction Patterns and Polarization

Diffraction and Polarization

- Diffraction can be described only with a wave model for light.
- A diffraction pattern occurs when the light from an aperture is allowed to fall on a screen .
  - The features of this diffraction pattern can be investigated.
- Under certain conditions transverse waves with electric field vectors in all directions can be polarized in various ways .
  - Only certain directions of the electric field vectors are present in the polarized wave.

Diffraction

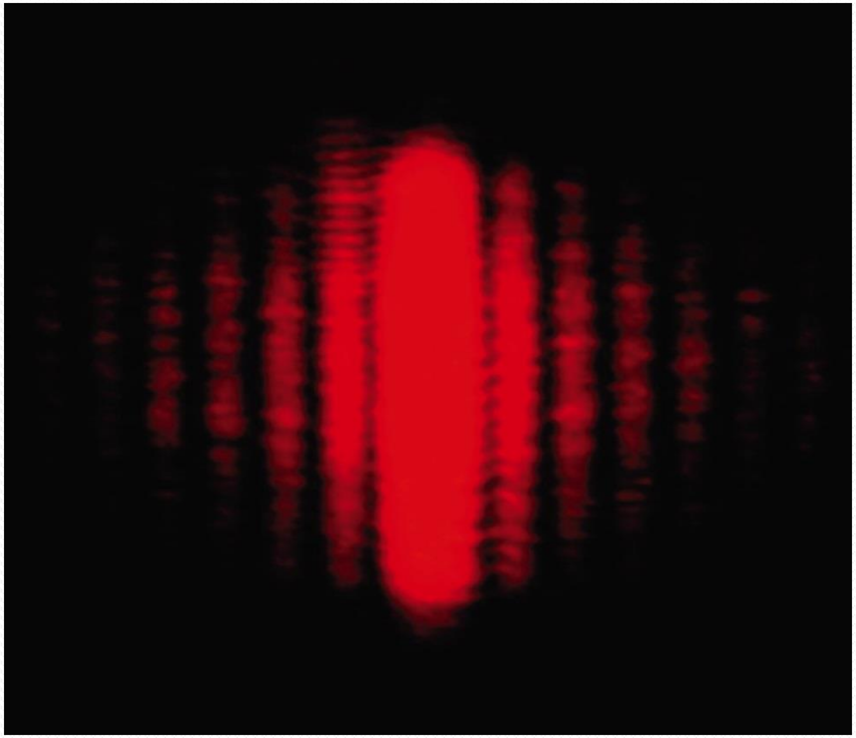
- Light of wavelength comparable to or larger than the width of a slit spreads out in all forward directions upon passing through the slit.
- This phenomena is called *diffraction.*
  - This indicates that light spreads beyond the narrow path defined by the slit into regions that would be in shadow if light traveled in straight lines.

Diffraction Pattern

- A single slit placed between a distant light source and a screen produces a **diffraction pattern.**
  - It will have a broad, intense central band
    - Called the **central maximum**
  - The central band will be flanked by a series of narrower, less intense secondary bands.
    - Called **side maxima** or **secondary maxima**
  - The central band will also be flanked by a series of dark bands.
    - Called **minima**

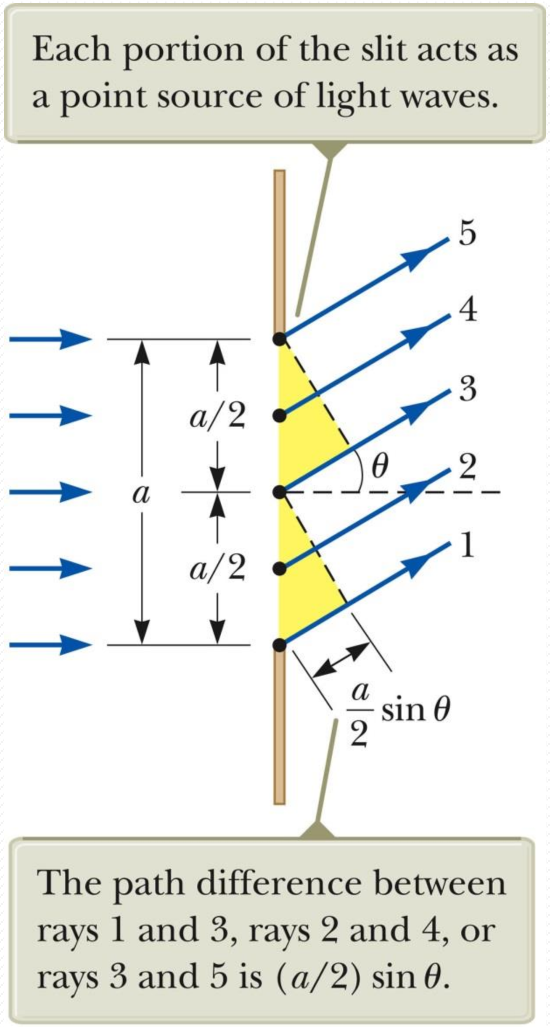
Diffraction Pattern, Single Slit

- The diffraction pattern consists of the central maximum and a series of secondary maxima and minima.
- The pattern is similar to an interference pattern.



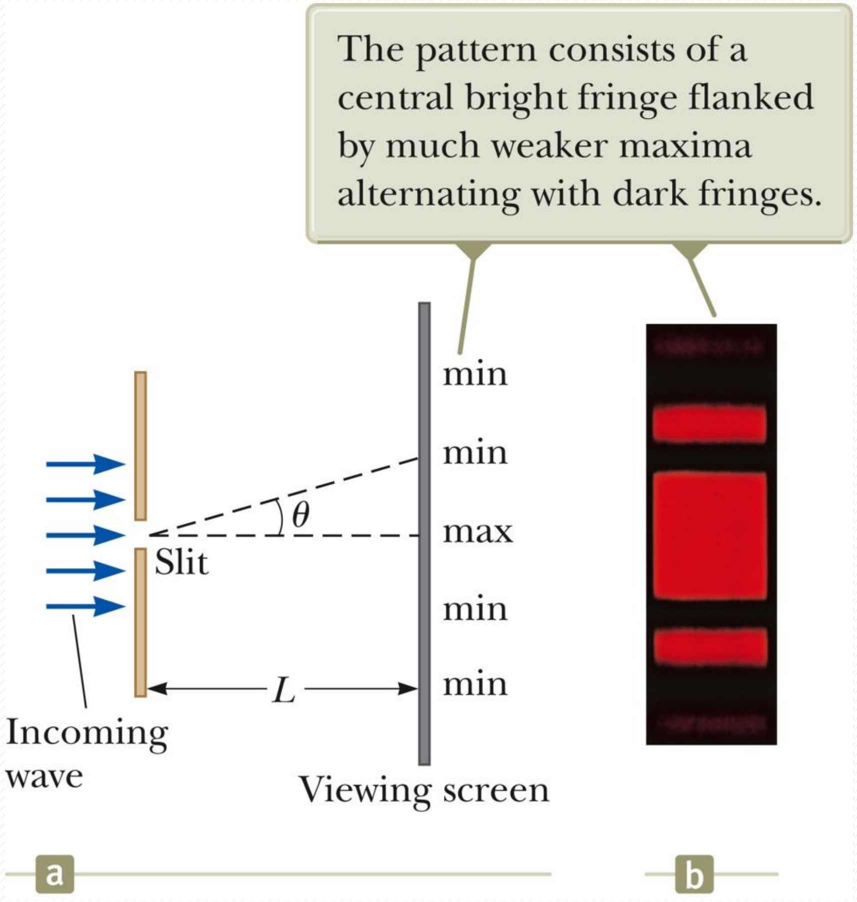
Single-Slit Diffraction, Analysis

- All the waves are in phase as they leave the slit.
- Wave 1 travels farther than wave 3 by an amount equal to the path difference.
    - $(a/2)\sin\theta$
- If this path difference is exactly half of a wavelength, the two waves cancel each other and destructive interference results.
- In general, destructive interference occurs for a single slit of width a when
- $\sin\theta_{dark} = m\lambda / a.$
    - $m = \pm 1, \pm 2, \pm 3, \ldots$



Single-Slit Diffraction, Intensity

- The general features of the intensity distribution are shown.
- A broad central bright fringe is flanked by much weaker bright fringes alternating with dark fringes.
- Each bright fringe peak lies approximately halfway between the dark fringes.
- The central bright maximum is twice as wide as the secondary maxima.
- There is no central dark fringe.
    - Corresponds to no m = 0 in the equation

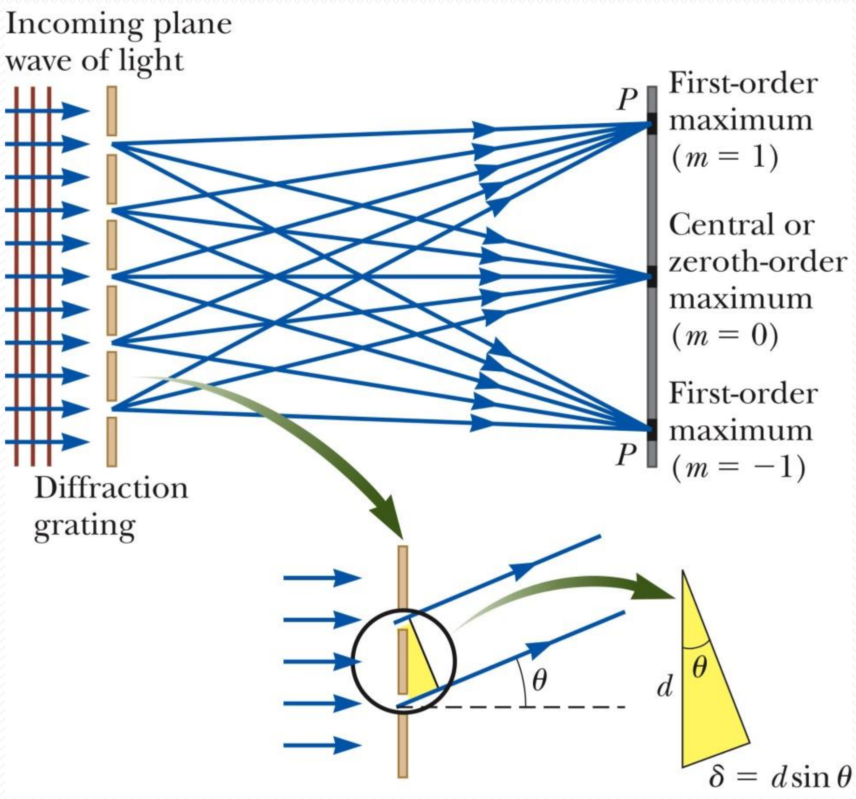


Diffraction Grating

- The diffracting grating consists of a large number of equally spaced parallel slits.
  - A typical grating contains several thousand lines per centimeter.
- The intensity of the pattern on the screen is the result of the combined effects of interference and diffraction.
  - Each slit produces diffraction, and the diffracted beams interfere with one another to form the final pattern.

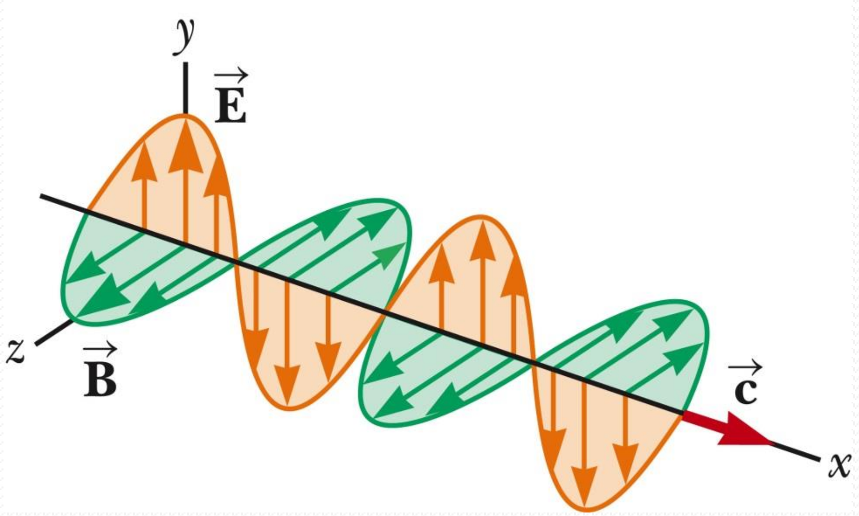
Diffraction Grating, cont.

- The condition for *maxima* is
  - $d \sin \theta_{\text{bright}} = m\lambda$
    - m = 0, ±1, ±2, …
- The integer *m* is the *order number* of the diffraction pattern.
- If the incident radiation contains several wavelengths, each wavelength deviates through a specific angle.



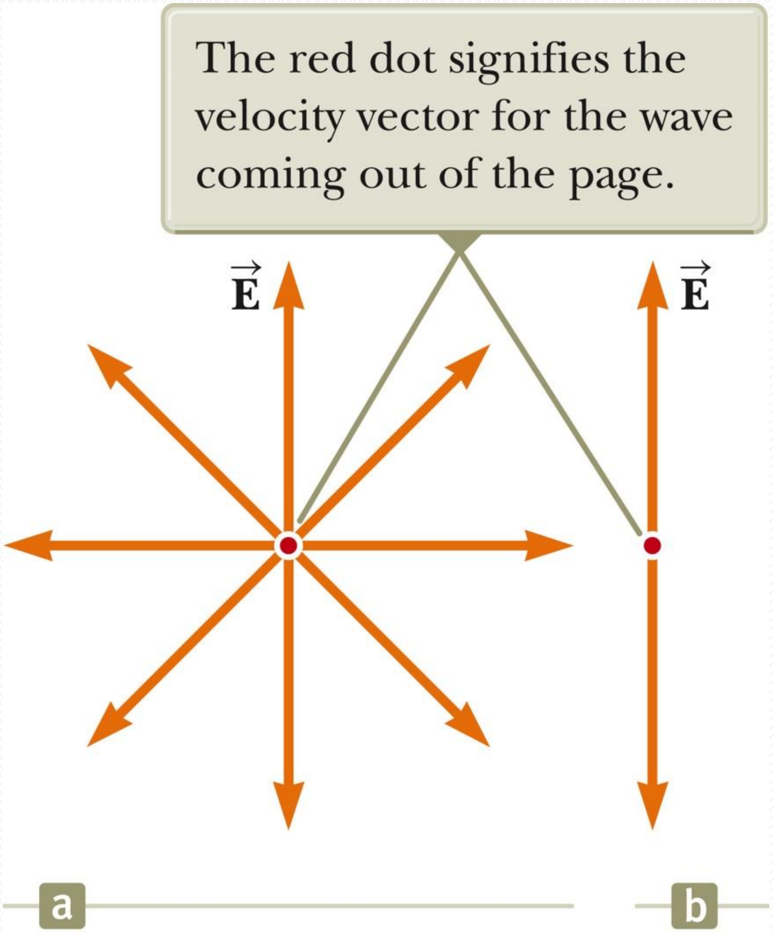
Polarization of Light Waves

- The *direction of polarization* of each individual wave is defined to be the direction in which the electric field is vibrating.
- In this example, the direction of polarization is along the *y*-axis.
- All individual electromagnetic waves traveling in the *x* direction have an electric field vector parallel to the *yz* plane.
- This vector could be at any possible angle with respect to the *y* axis.



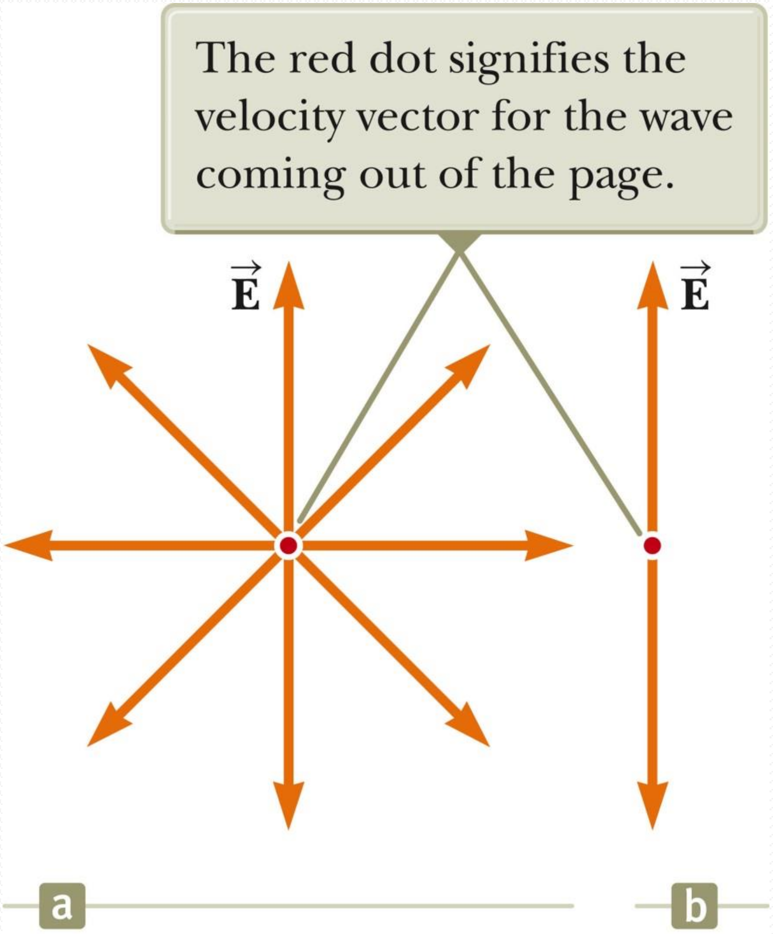
Unpolarized Light, Example

- All directions of vibration from a wave source are possible.
- The resultant em wave is a superposition of waves vibrating in many different directions.
- This is an unpolarized wave.
- The arrows show a few possible directions of the waves in the beam.



Polarization of Light, cont.

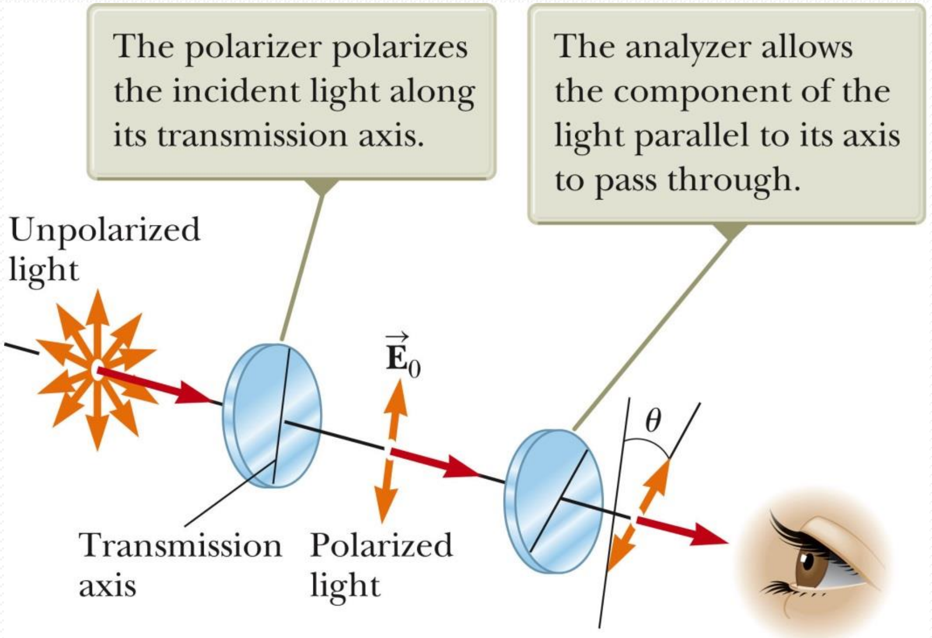
- A wave is said to be *linearly polarized* if the resultant electric field vibrates in the same direction *at all times* at a particular point.
- The plane formed by the field and the direction of propagation is called the *plane of polarization* of the wave.



Methods of Polarization

- It is possible to obtain a linearly polarized beam from an unpolarized beam by removing all waves from the beam except those whose electric field vectors oscillate in a single plane.
- Processes for accomplishing this include:
  - Selective absorption
  - Reflection
  - Double refraction
  - Scattering

Polarization by Selective Absorption



- The most common technique for polarizing light.
- Uses a material that transmits waves whose electric field vectors lie in the plane parallel to a certain direction and absorbs waves whose electric field vectors are in all other directions.

Polarization by Reflection

- When an unpolarized light beam is reflected from a surface, the reflected light may be
  - Completely polarized
  - Partially polarized
  - Unpolarized
- The polarization depends on the angle of incidence.
  - If the angle is 0°, the reflected beam is unpolarized.
  - For other angles, there is some degree of polarization.
  - For one particular angle, the beam is completely polarized.

Polarization by Reflection, cont.

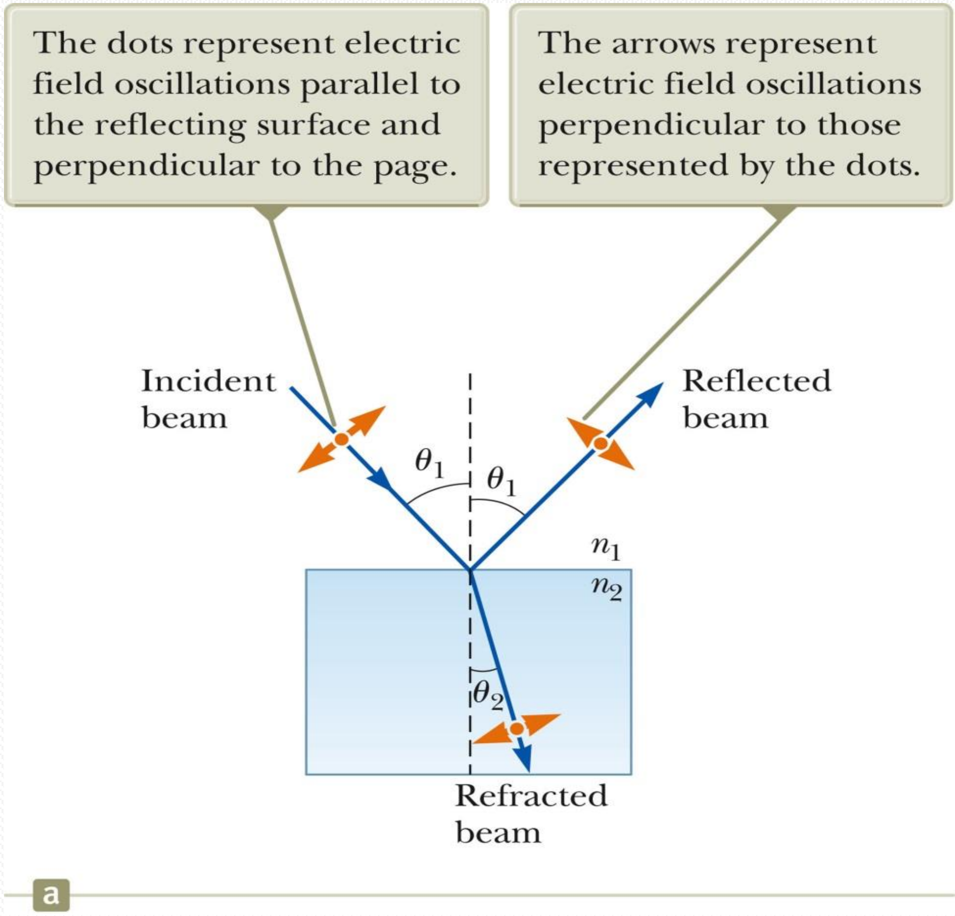
- The angle of incidence for which the reflected beam is completely polarized is called the polarizing angle, θ_p.
- **Brewster's law** relates the polarizing angle to the index of refraction for the material.

$$\tan \theta_p = \frac{n_2}{n_1}$$

- θ_p may also be called Brewster's angle.

Polarization by Reflection, Partially Polarized Example

- Unpolarized light is incident on a reflecting surface.
- The reflected beam is partially polarized.
- The refracted beam is partially polarized



Polarization by Reflection, Completely Polarized Example

- Unpolarized light is incident on a reflecting surface.
- The reflected beam is completely polarized.
- The refracted beam is perpendicular to the reflected beam.
- The angle of incidence is Brewster's angle.