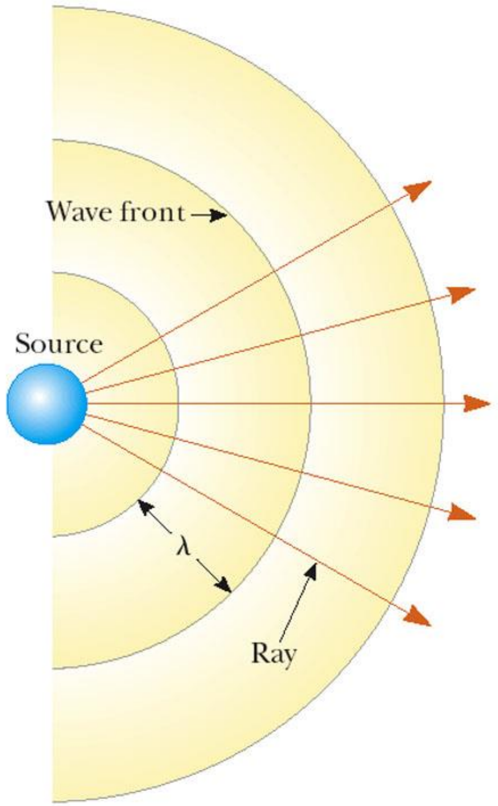
Section 4.3

Wave Characteristics

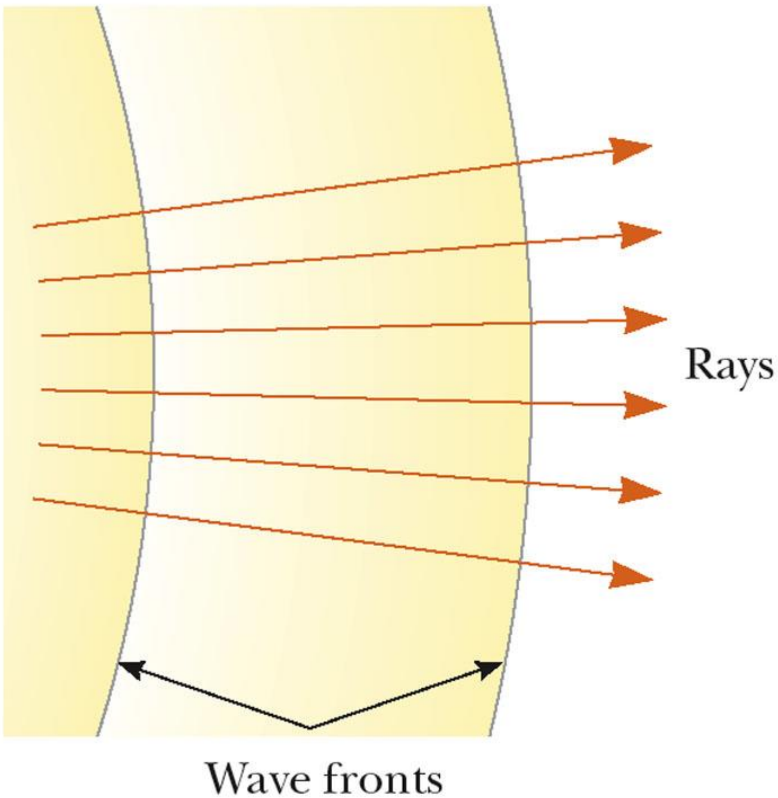
Representations of Waves

- *Circular Wave fronts* are the concentric arcs
  - The distance between successive wave fronts is the wavelength
- *Rays* are the radial lines pointing out from the source and perpendicular to the wave fronts



Plane Wave

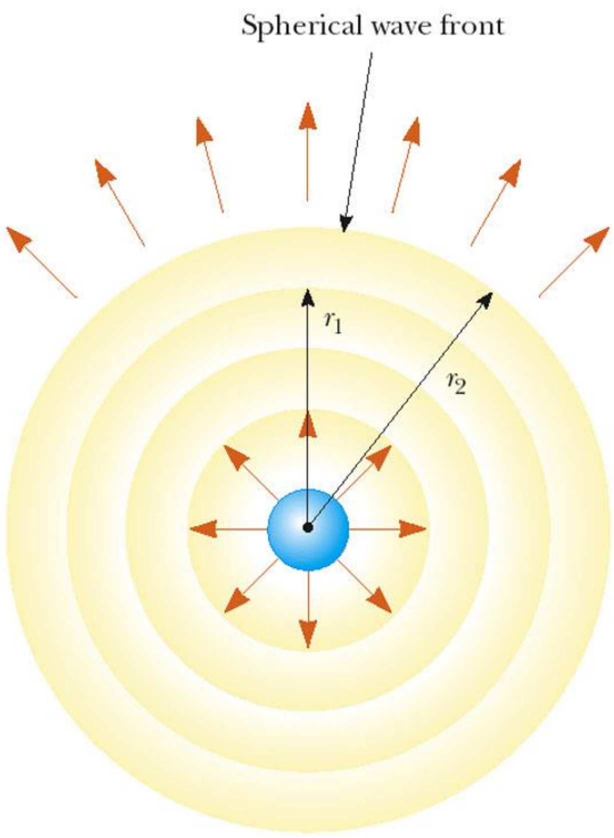
- Far away from the source, the wave fronts are nearly parallel planes
- The rays are nearly parallel lines
- A small segment of the wave front is approximately a plane wave



Spherical Waves

- A spherical wave propagates radially outward from the oscillating sphere
- The energy propagates equally in all directions
- The intensity is

$$I = \frac{P}{A} = \frac{P}{4\pi r^2}$$

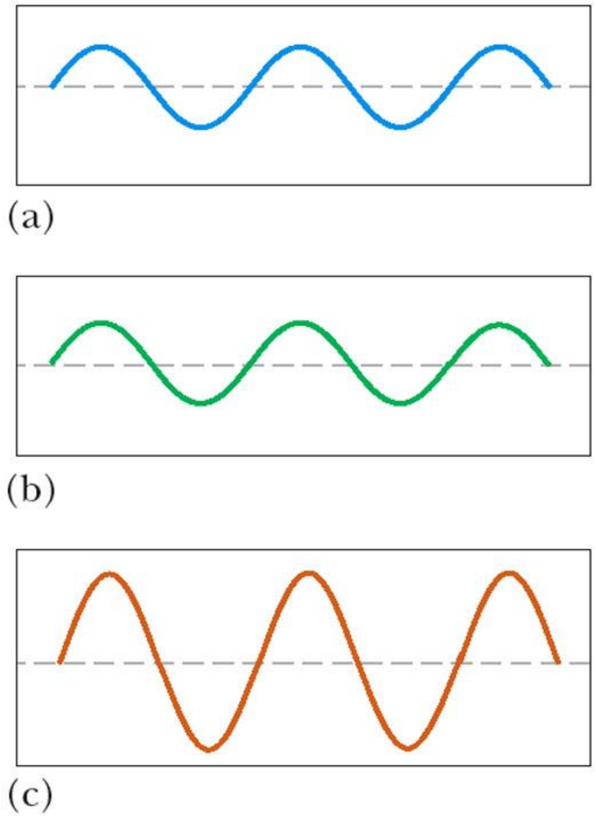


Interference of Waves

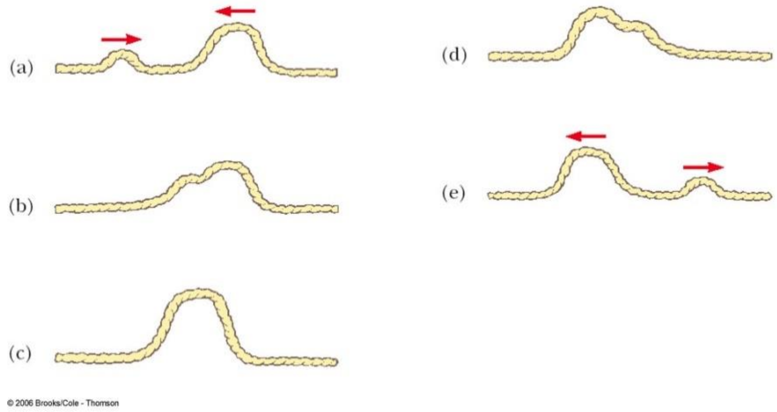
- Two traveling waves can meet and pass through each other without being destroyed or even altered
- Waves obey the *Superposition Principle*
  - If two or more traveling waves are moving through a medium, the resulting wave is found by adding together the displacements of the individual waves point by point
  - Actually only true for waves with small amplitudes

Constructive Interference

- Two waves, a and b, have the same frequency and amplitude
  - Are *in phase*
- The combined wave, c, has the same frequency and a greater amplitude



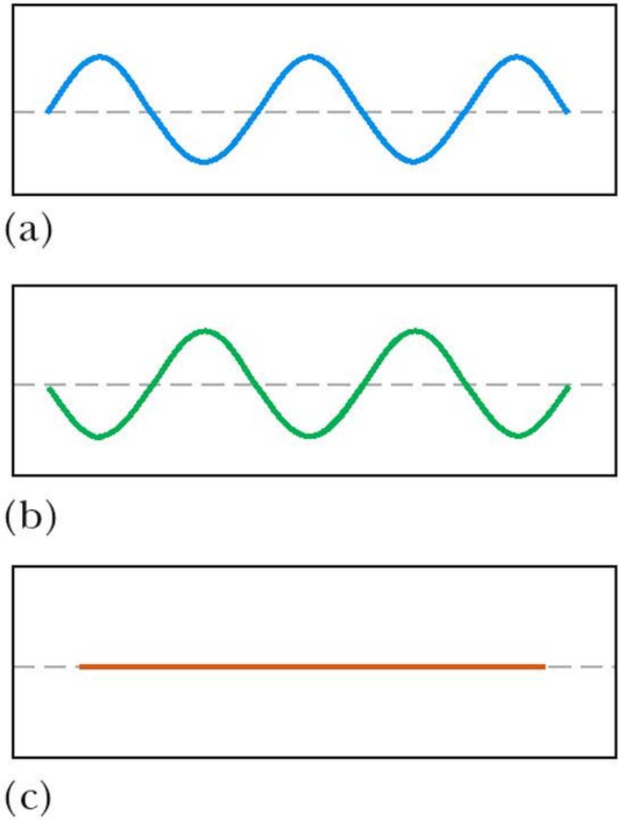
Constructive Interference in a String



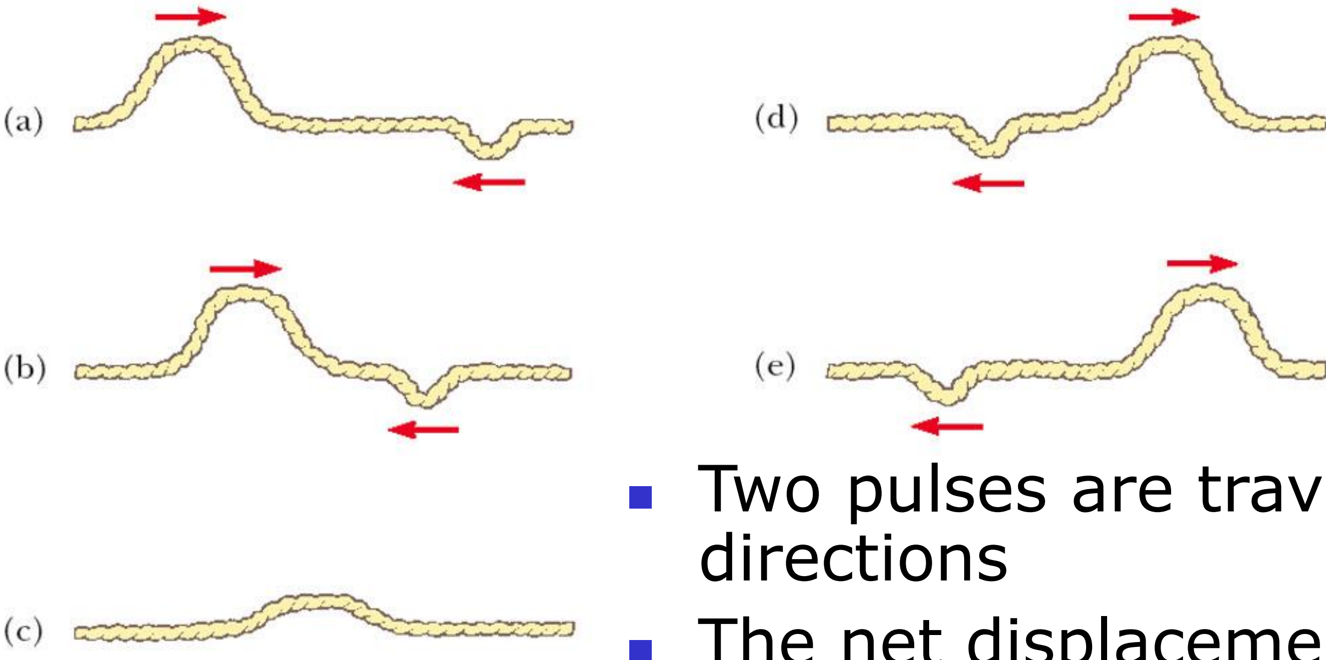
- Two pulses are traveling in opposite directions
- The net displacement when they overlap is the sum of the displacements of the pulses
- Note that the pulses are unchanged after the interference

Destructive Interference

- Two waves, a and b, have the same amplitude and frequency
- They are 180° out of phase
- When they combine, the waveforms cancel



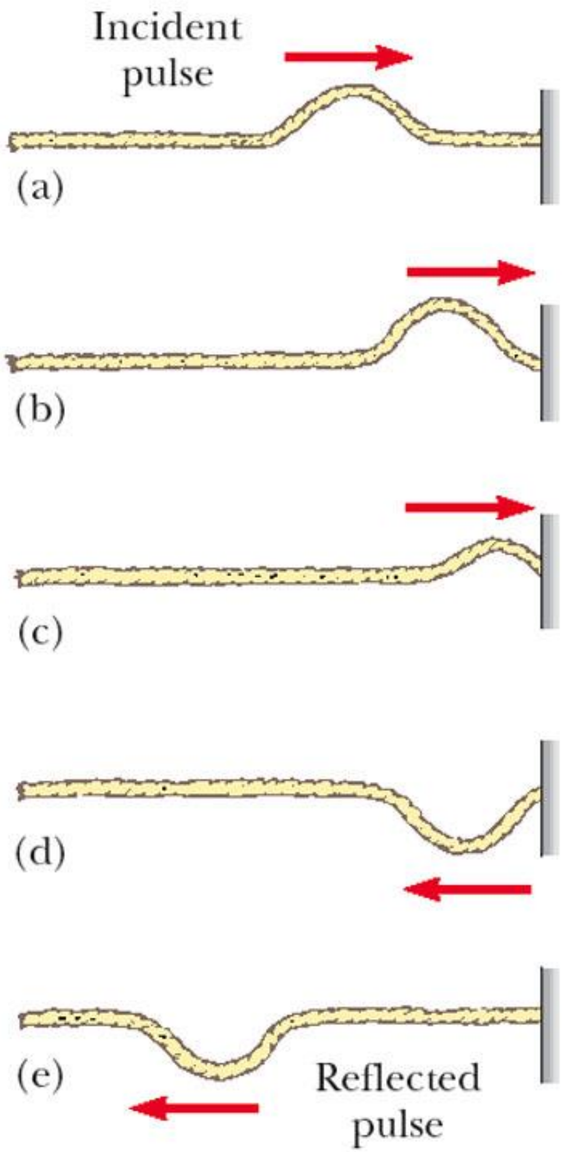
Destructive Interference in a String



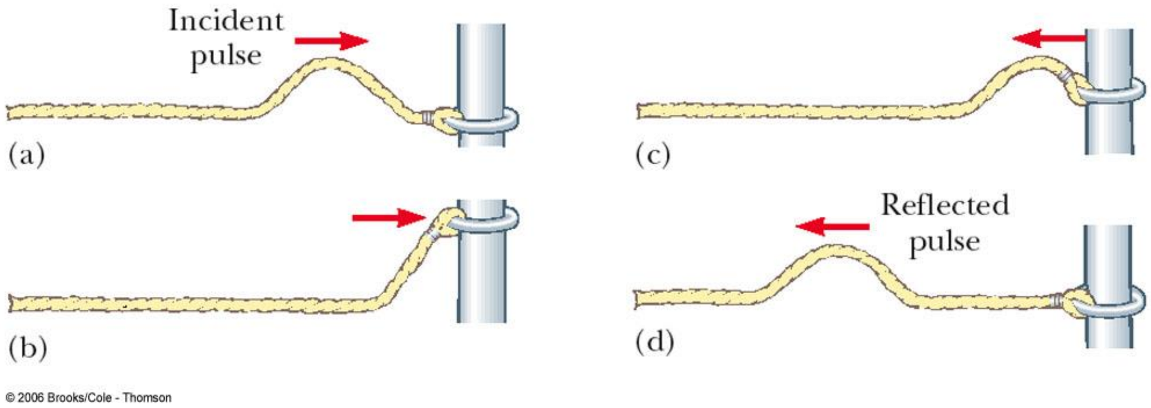
- Two pulses are traveling in opposite directions
- The net displacement when they overlap is decreased since the displacements of the pulses subtract
- Note that the pulses are unchanged after the interference

Reflection of Waves – Fixed End

- Whenever a traveling wave reaches a boundary, some or all of the wave is reflected
- When it is reflected from a fixed end, the wave is inverted
- The shape remains the same

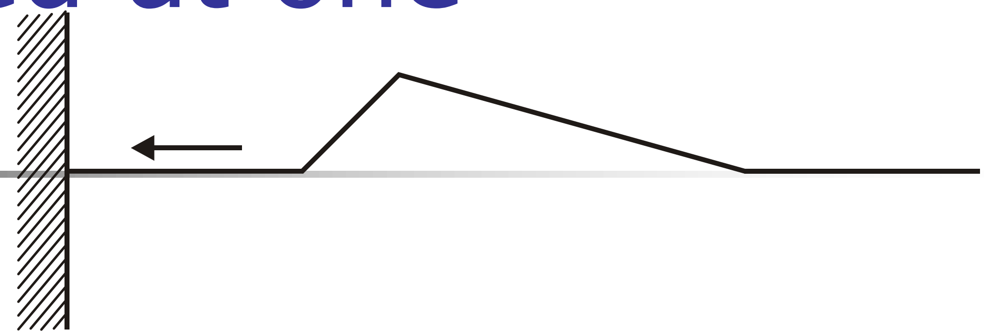


Reflected Wave – Free End



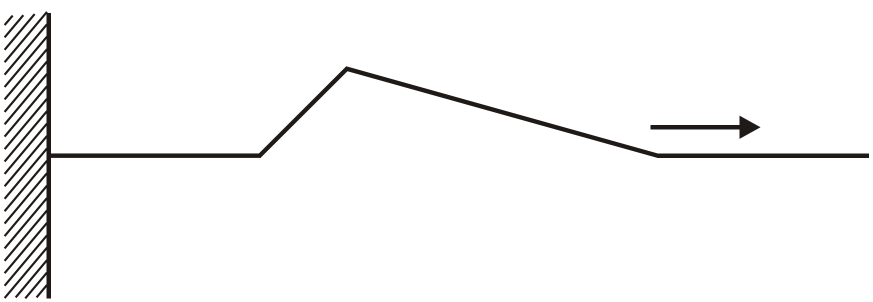
- When a traveling wave reaches a boundary, all or part of it is reflected
- When reflected from a free end, the pulse is not inverted

A pulse is sent down a string fixed at one end.

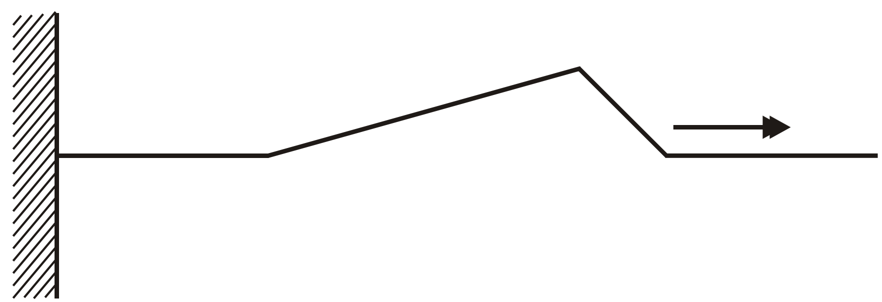


Which **one** of the following diagrams best represents the reflected pulse?

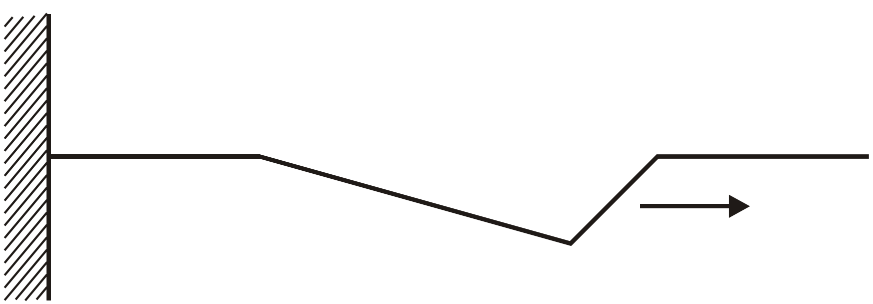
A.



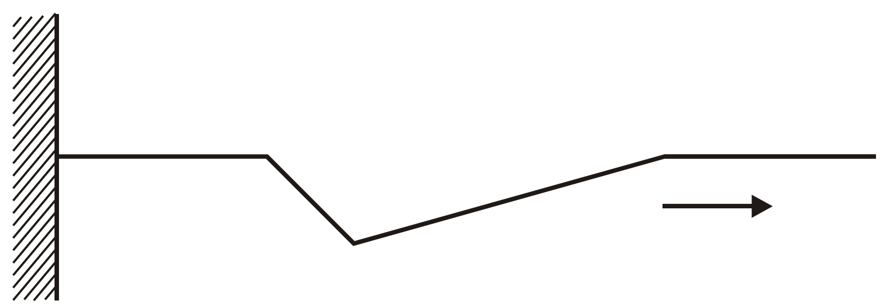
B.



C.

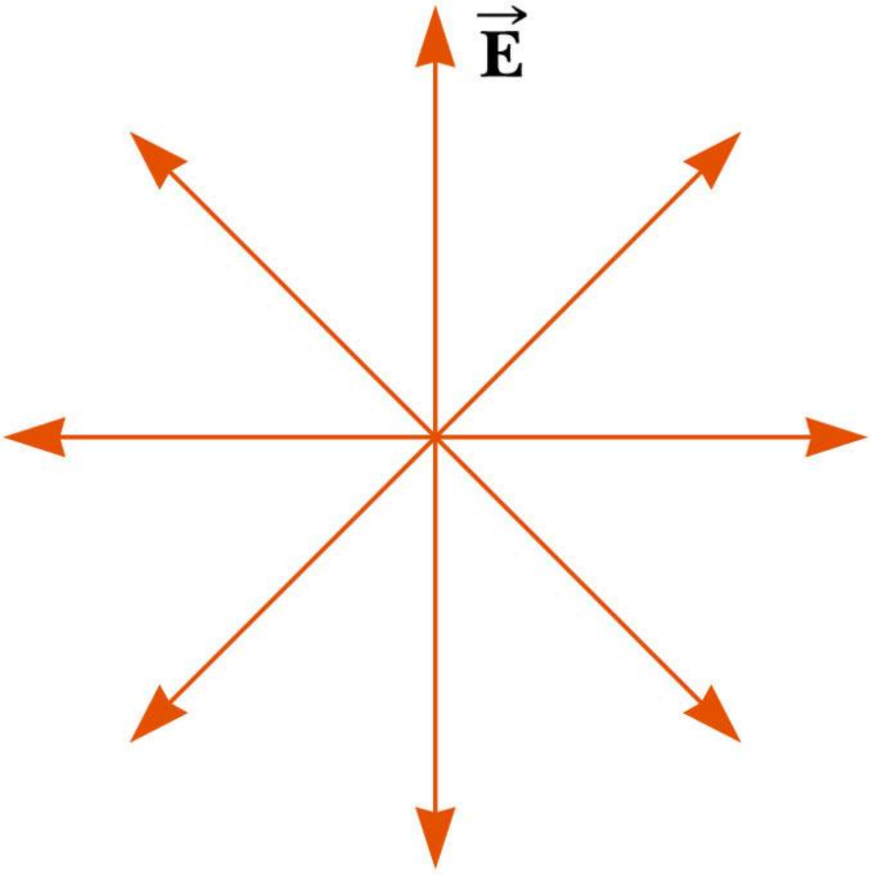


D.



Polarization of Light Waves

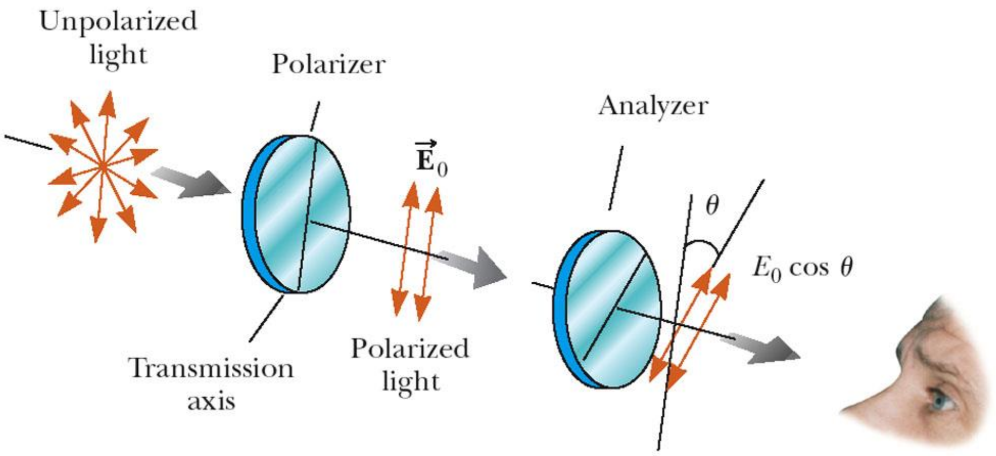
- Each atom produces a wave with its own orientation of $\vec{\mathbf{E}}$
- All directions of the electric field vector are equally possible and lie in a plane perpendicular to the direction of propagation
- This is an unpolarized wave



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
- Polarization can be obtained from an unpolarized beam by
  - selective absorption
  - reflection
  - scattering

Polarization by Selective Absorption



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

Selective Absorption, cont

- E. H. Land discovered a material that polarizes light through selective absorption
  - He called the material **Polaroid**
  - The molecules readily absorb light whose electric field vector is parallel to their lengths and transmit light whose electric field vector is perpendicular to their lengths

Selective Absorption, final

- The intensity of the polarized beam transmitted through the second polarizing sheet (the analyzer) varies as
  - $I = I_o \cos^2 \theta$
    - I_o is the intensity of the polarized wave incident on the analyzer
    - This is known as **Malus' Law** and applies to any two polarizing materials whose transmission axes are at an angle of θ to each other

Polarization by Reflection

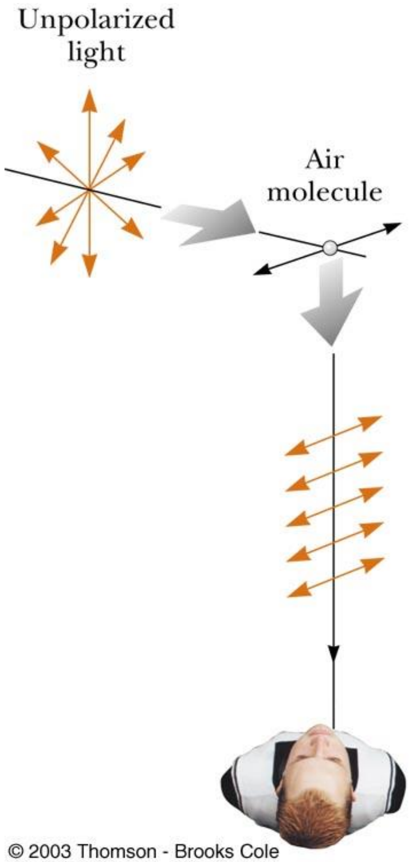
- When an unpolarized light beam is reflected from a surface, the reflected light is
  - Completely polarized
  - Partially polarized
  - Unpolarized
- It depends on the angle of incidence
  - If the angle is 0° or 90°, the reflected beam is unpolarized
  - For angles between this, there is some degree of polarization
  - For one particular angle, the beam is completely polarized

Polarization by Scattering

- When light is incident on a system of particles, the electrons in the medium can absorb and reradiate part of the light
  - This process is called **scattering**
- An example of scattering is the sunlight reaching an observer on the earth becoming polarized

Polarization by Scattering, cont

- The horizontal part of the electric field vector in the incident wave causes the charges to vibrate horizontally
- The vertical part of the vector simultaneously causes them to vibrate vertically
- Horizontally and vertically polarized waves are emitted



Optical Activity

- Certain materials display the property of *optical activity*
  - A substance is optically active if it rotates the plane of polarization of transmitted light
  - Optical activity occurs in a material because of an asymmetry in the shape of its constituent materials