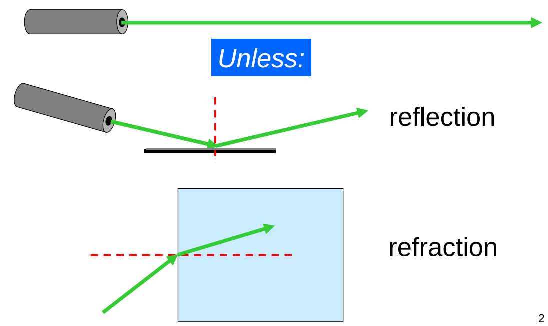
L 32 Light and Optics-4

- Up to now we have been studying <u>geometric optics</u>
- Today we will look at effects related to the *wave nature of light* – <u>physical optics</u>
  - – polarization
  - – interference
    - thin film interference
    - diffraction
    - resolving close objects

1

Light “rays” travel in straight lines



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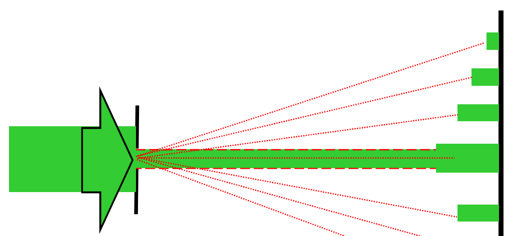
Effects due to the *wave nature* of light

- Thus far we have been dealing only with **geometrical optics**
- In geometrical optics we deal only with the behavior of light rays → it either travels in a straight line or is reflected by a mirror, or bent (refracted) when it travels from one medium into another.
- However, light is a ***WAVE***, and there are certain properties that can only be understood by taking into account the wave nature of light.

3

Diffraction: *bending of light passing through an aperture (hole)*



A simple shadow of the slit is not observed, because the light spreads out when passing through it.

4

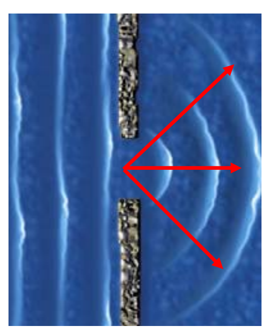
Wave or physical optics

- We will consider two effects that are related to the wave properties of light
  - polarization
  - interference
- everyday examples:
  - Polaroid lenses
  - the colors of an oil film

Laser passing through a pinhole

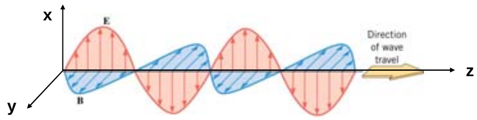
5

Diffraction of water waves



6

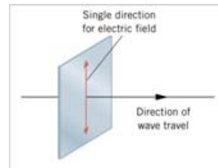
Polarization



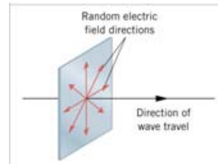
- Light is an electromagnetic wave with the electric and magnetic field having very specific orientations
- A light wave in which the electric field always vibrates along one direction is called a *linearly polarized* wave
- The direction of polarization is the axis along which the electric field vibrates
- In the diagram above, the wave polarization is x

Polarization-a

- the direction in which the electric field vibrates is the direction of polarization
- with *polarized* light the electric field always vibrates in one direction
- ordinary light is *unpolarized* so that the electric field is randomly oriented about the direction of travel

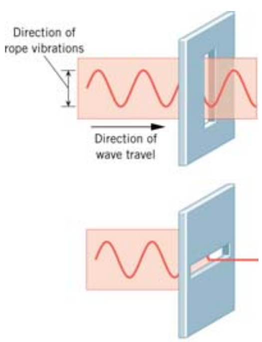


Polarized light



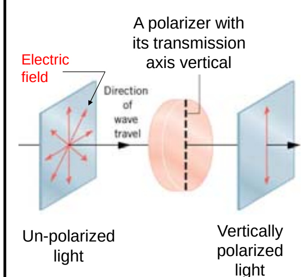
Un-polarized light

Polarization-b



- a transverse wave is linearly polarized with its vibrations always along one direction
- a linearly polarized wave can pass through a slit that is parallel to the vibration direction
- the wave cannot pass through a slit that is perpendicular to the vibration direction

Polaroid Sheets



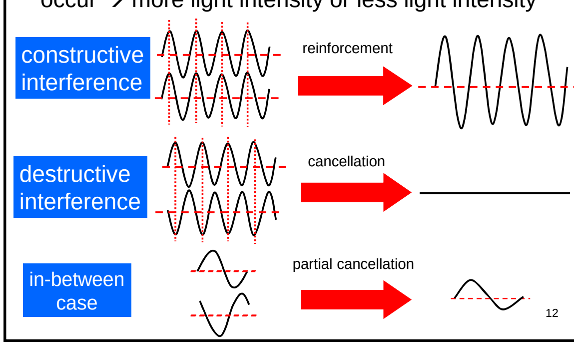
- a polarizing material (polarizer) will only allow the polarization parallel to its axis to pass through thus, it reduces the light intensity
- 2 polarizers can be used to control the light intensity
- Sunglasses made from polarizing material are used to remove "glare," light reflected from a surface and tend to be polarized

Polaroid sunglasses

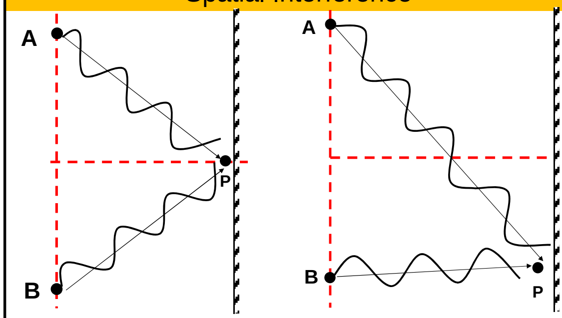
When unpolarized light passes successively through 2 polarizers whose axes are oriented 90 degrees to each other, no light will emerge. The first one polarizes the light, and the second one then blocks it.

interference of light

when two light waves are combined, interference can occur → more light intensity or less light intensity



Spatial Interference



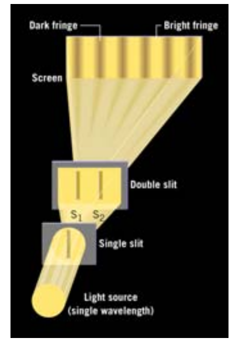
Waves leave A and B in phase, travel the same distance to P, and arrive in phase. P is a bright spot → Constructive interference

Waves leave A and B in phase, but travel different distances to P, and arrive out of phase. P is a dark spot → Destructive interference

13

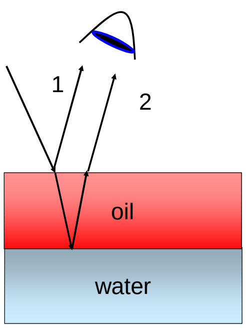
two-slit interference

Each slit of the double slit acts as a new source of light. Light waves from the two sources then interfere constructively in places producing the bright fringes, while in other places they interfere destructively producing dark fringes.



14

thin film interference



Ray 1 is reflected from the oil surface. Ray 2 is the ray resulting from refraction at the gasoline/ water surface. Since the rays travel different paths, they interfere when combined. Different wavelengths interfere at different places → the produces **COLORS**

15

Soap bubbles are thin films

16

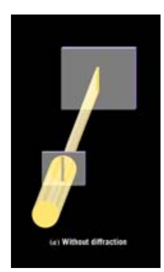
Interference from a CD

- Whenever light bounces off a surface having a regular array of grooves (like a CD) interference occurs.
- An optical device that uses this effect is called a diffraction grating.

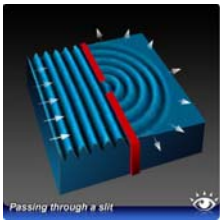
17

Diffraction

- An important interference effect is the spreading of light as it passes through a narrow opening.
- without diffraction, light passing through a narrow slit would just produce a shadow effect.
- The effect of diffraction is to cause the light to spread out around the edges of the slit



18



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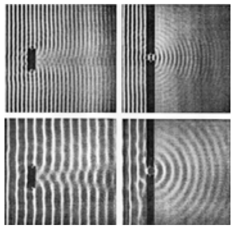
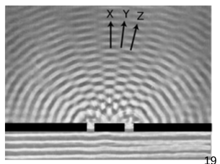
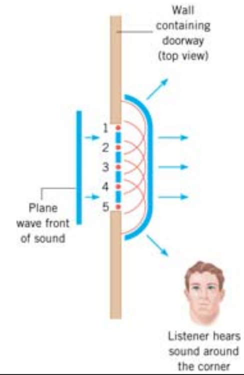




19

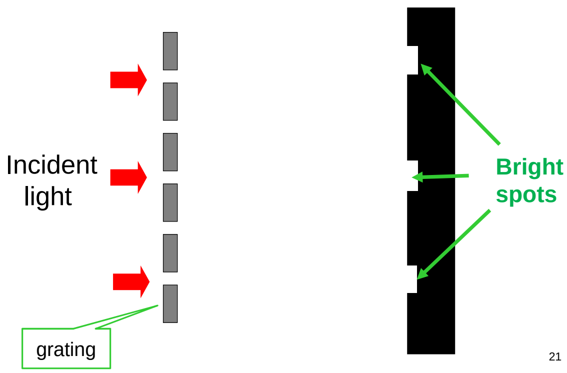
diffraction of sound

- the diffraction of sound waves explains why we can hear sound around corners
- diffraction of sound around the head makes hearers misjudge the location of sound sources



20

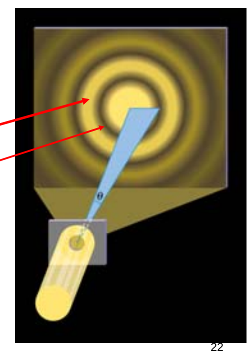
A diffraction grating



21

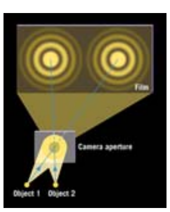
Light passing through a pinhole

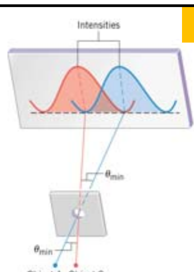
A pattern of concentric bright rings and dark rings is formed called interference fringes.

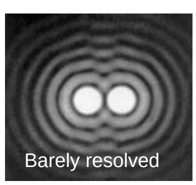


22

Diffraction effects



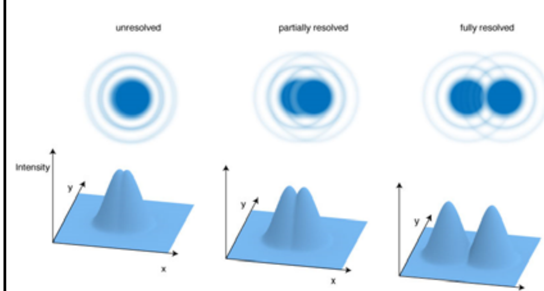




- Diffraction limits our ability to distinguish closely spaced objects because it causes the images to overlap
- Diffraction limits the size of an object on the ground that can be photographed from a satellite

23

Lord Rayleigh established a criterion for objects to be barely resolved



Diffraction affects the resolution of close objects

The automobile headlights were photographed from various distances from the camera.

camera close to car

camera far from car

25