L 34 Light and Optics [4]

- Measurements of the speed of light
- The bending of light – refraction
  - Total internal reflection
  - Dispersion
- Dispersion
  - Rainbows
- Atmospheric scattering
  - Blue sky
  - red sunsets

Light and optics

- images formed by mirrors
  - plane mirrors
  - curved mirrors
  - concave
  - convex
- the human eye
  - correcting vision problems
    - nearsightedness
    - farsightedness
    - astigmatism
  - depth perception

- dispersion
- rainbows
- atmospheric scattering
- blue sky
- red sunsets

Light “rays” travel in straight lines

- effects related to the wave nature of light
  - polarization
  - interference
    - thin film interference
    - diffraction
    - resolving close objects

Effects due to the wave nature of light

- Thus far we have been dealing only with what is called geometrical optics
- In geometrical optics we deal only with the behavior of light rays if 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.

Diffraction: bending of light passing through an aperture (hole)
Wave or physical optics

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

polarization

- as we mentioned before, light is an electromagnetic wave and so consists of both an electric and magnetic field, as shown below

| a linearly polarized wave |

polarization

- 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

Polaroid lenses

- a polarizing material or polaroid lens will only allow the polarization parallel to its axis to pass through
- thus, it reduces the light intensity
- polaroid lenses are very useful in eliminating “glare” — reflected light which tends to be polarized

Polaroid sunglasses

- 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
interference of light

- when two light waves are combined, either constructive or destructive interference can occur – more light intensity or less light intensity.

**constructive interference**

**destructive interference**

Two waves that start out in sync at points A and B reach point P after traveling different paths. They arrive at P no longer in sync and hence can interfere destructively when combined at P.

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two-slit interference

Ray 1 is reflected from the gasoline 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 color is **color**.

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thin film interference

Soap bubbles are thin films

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.
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.

Diffraction of water waves

Diffraction of sound

- The diffraction of sound waves explains why we can hear sound around corners.

A diffraction grating

Light passing through a pinhole

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

Diffraction limits our ability to resolve closely spaced objects because it causes the images to overlap. Diffraction is what sets a limit on the size of objects on the earth that can be imaged from space.
The automobile headlights were photographed from various distances from the camera closest in (a) and farthest in (c). In part (c) the headlights are so far away that they are barely distinguishable.

(a) (b) (c)