PHY 203- PHYSICS III

Light and optics

Nature of Light

Particle theory of Greek (corpuscular)
Before 19th century-Newton- Particle theory
1678- Huygens- wave theory-explains reflection and refraction
1801- Young- proof of wave theory- interference experiment
A Few years later-Fresnel-interference diffraction experiment
1850-Foucault-particle theory is not enough-speed of the light is slower in water
1873-Maxwell-elektromagnetic wave theory
1887-Hertz-proof of electromagnetic wave theory
Hertz-Fotoelectric effect-contradicts the wave theory
1900-Max Planck-particle theory-quantum phenomena
1905-Einstein-Explanation of photoelectric effect-Photon

Energy of a photon $E=hf$,

$h=6.63\times10^{-34}$ J.s Planck constant, f-frequency of a photon

Nature of Light

- **Newton improved particle theory of light (corpuscular).**

•Light was considered to be a stream of particles that either was emitted by the object being viewed or emanated from the eyes
of the viewer.

•It explains sharp shadow

•It explains reflection and refraction

Roemer Method-1975
(Danish Astronomer)

- 1 year of Jupiter=12 years of Earth
- Earth moves through 90° around the sun, Jupiter revolves through only (1/12).90°=7.5°.
- One of the moons of Jupiter has a period of revolution around Jupiter of approximately 42.5 hours.
- After collecting data for more than an year it was found that period was delayed 600 second at every 3 months.
- Roemer thought it is because the distance between the Earth and Jupiter was changed from one observation to the next.
- In three months (1/4 Earth year),the light from Jupiter must travel an additional distance equal to the radius of Earth's orbit.

Fizeau Method-1849 (French Physicist)

- The basic procedure is to measure the total time interval during which light travels from some point to a distant mirror and back.

Time interval: Δt

Distance light travelled: $2d$

$c = 2d/\Delta t = 3.1 \times 10^8$ m/s

Example 35.1-Fizeau experiment

- Assume that Fizeau's wheel has 360 teeth and is rotating at
- 27.5 rev/s when a pulse of light passing through opening A
- in Figure 35.2 is blocked by tooth B on its return. If the
- distance to the mirror is 7 500 m, what is the speed of light?

- **Solution**: The wheel has 360 teeth, and so it must have 360 openings. Therefore, because the light passes through opening A but is blocked by the tooth immediately adjacent to A, the wheel must rotate through an angular displacement of (1/720) rev in the time interval during which the light pulse
- makes its round trip.

$$\Delta t = \frac{\Delta\theta}{\omega} = \frac{(1/720)\text{ rev}}{27.5\text{ rev/s}} = 5.05 \times 10^{-5}\text{ s}$$

$$c = \frac{2d}{\Delta t} = \frac{2(7\,500\text{ m})}{5.05 \times 10^{-5}\text{ s}} = \boxed{2.97 \times 10^{8}\text{ m/s}}$$

Limitations of geometric optics

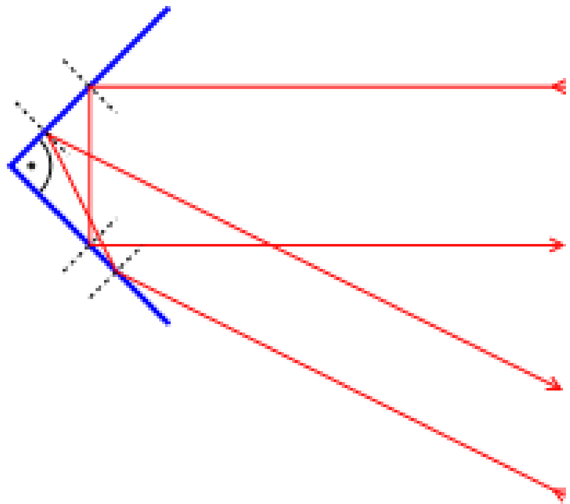
- Geometric optics ignore the phase of the waves.
- Geometrical optics assumes that light is focused to a point with zero diameter.
- This is not correct. The smallest diameter of light at focus is equal to approximatelly the wavelenth λ of the light wave. This is due to the wave nature of the light and it limits the resolution of the formed images at focus. Geometric optics ignore this property.

Why is it difficult to see while driving in a rainy night?

•If the road is wet, the smooth surface of the water specularly reflects most of your headlight beams away from your car (and perhaps into the eyes of oncoming drivers).

•When the road is dry, its rough surface diffusely reflects part of your headlight beam back toward you, allowing you to see the highway more clearly.

Retroreflector Mirrors



If the angle between two mirrors is 90° , the reflected beam returns to the source parallel to its original path. This phenomenon, called *retroreflection*, has many practical applications.

If a third mirror is placed perpendicular to the first two, so that the three form the corner of a cube,
retroreflection works in three dimensions.

Where do we use these mirrors?

Application of retroreflective mirrors

(a) In 1969, a panel of many small reflectors was placed on the Moon by the *Apollo 11* astronauts A laser beam from the Earth is reflected directly back on itself and its transit time is measured. This information is used to determine the distance to the Moon with an uncertainty of 15 cm.

(b) (b) Part of the plastic making up the automobile taillight is formed into many tiny cube corners so that headlight beams from cars approaching from the rear are reflected back to the drivers.

(c) (c) Tiny clear spheres are used in a coating material found on many road signs.

Example
An Index of Refraction Measurement

- A beam of light of wavelength 550 nm traveling in air is incident
- on a slab of transparent material. The incident beam makes an angle of 40.0° with the normal, and the refracted beam makes an angle of 26.0° with the normal. Find the index of refraction of the material.

$$n_1 = 1.00$$

$$n_1 \sin \theta_1 = n_2 \sin \theta_2$$

$$n_2 = \frac{n_1 \sin \theta_1}{\sin \theta_2} = (1.00) \frac{\sin 40.0^\circ}{\sin 26.0^\circ}$$

$$= \frac{0.643}{0.438} = \boxed{1.47}$$

Example
Laser Light in a Compact Disc

A laser in a compact disc player generates light that has a wavelength of 780 nm in air. **(A)** Find the speed of this light once it enters the plastic of a compact disc (*n* =1.55). **(B)** What is the wavelength of this light in the plastic?

$$v = \frac{c}{n} = \frac{3.00 \times 10^8 \text{ m/s}}{1.55}$$

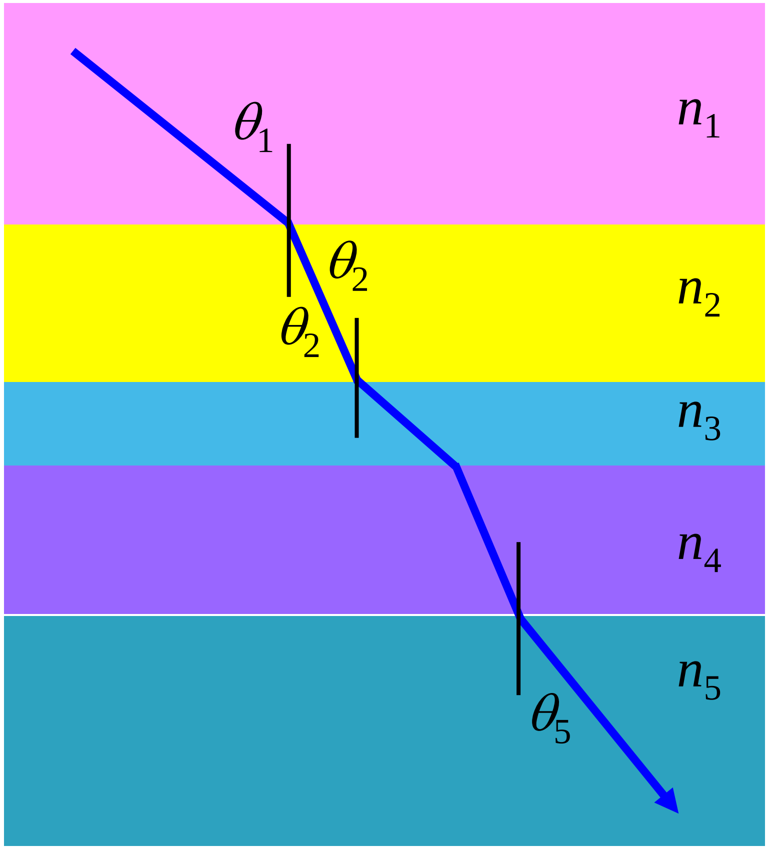
$$v = \boxed{1.94 \times 10^8 \text{ m/s}}$$

$$\lambda = 780 \text{ nm}$$

$$\lambda_n = \frac{\lambda}{n} = \frac{780 \text{ nm}}{1.55} = \boxed{503 \text{ nm}}$$

Fermat’s Principle

Fermat’s principle states that when a light ray travels between any two points, its path is the one that requires the smallest time interval.



An obvious consequence of this principle is that the paths of light rays traveling in a homogeneous medium are straight lines because a straight line is the shortest distance between two points.