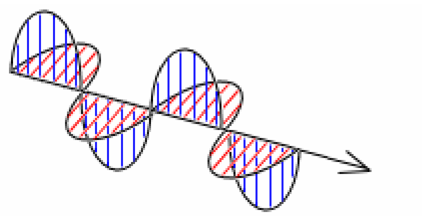
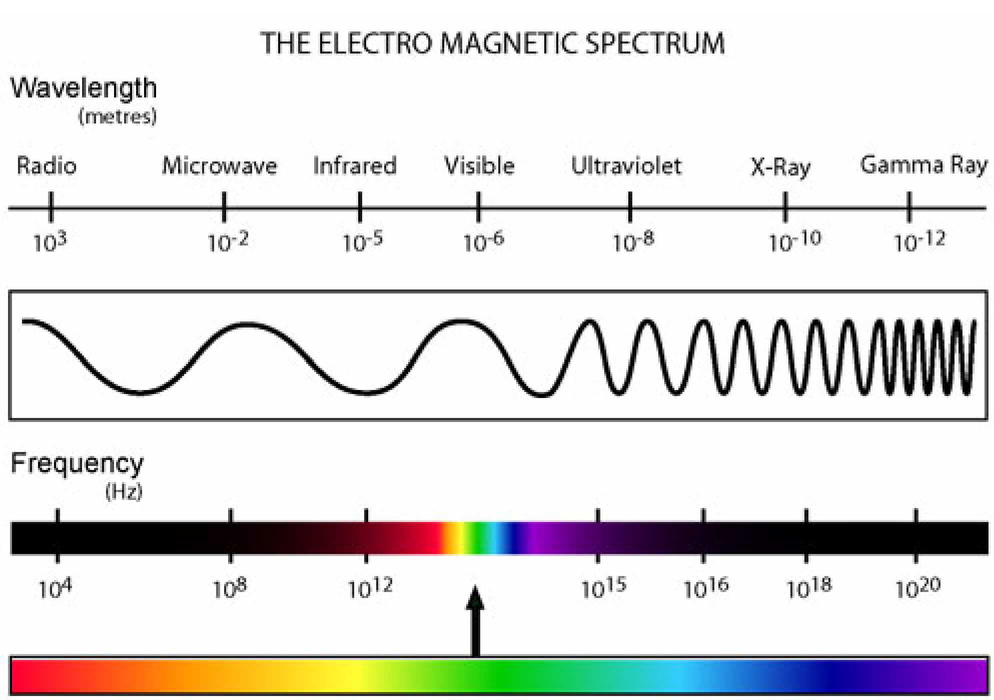
Chapter 8 – Light

Light…

- acts as a wave and a particle – we think of the wave properties of light in this chapter
- is a wave of electric and magnetic fields
  - thus the term "electromagnetic radiation"
  - thus light can move in these fields even in a vacuum
- is a transverse wave
  - fields oscillate at right angles to the direction of movement of the wave and at right angles to each other



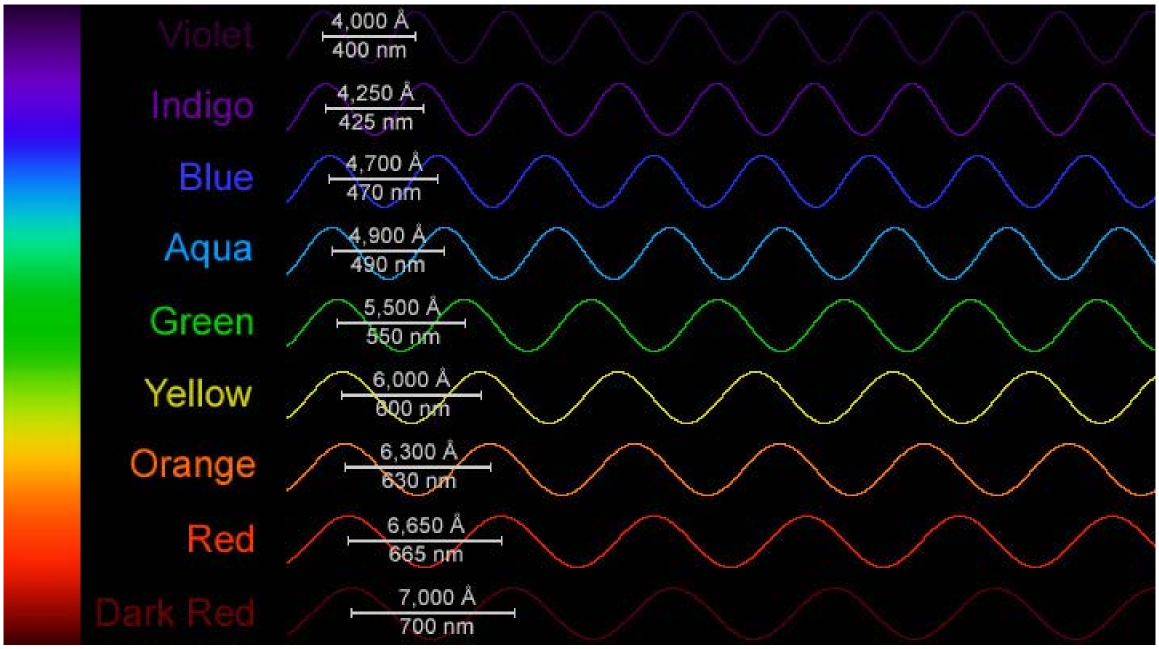
- is emitted from and causes the vibration of electrons
- does not appear to us as a wave because of its high frequency and short wavelength
- in the spectrum visible to us is just a small part of the electromagnetic spectrum



- has frequency (i.e., color) and wavelength that can be related by the equation

$$v = f \cdot L \text{ or } f = \frac{v}{L}$$

where f is frequency, L is wavelength, and v is the speed of light (for light moving in a vacuum, $v = c \cong 3x10^8 m/s$)



Color	L (nm)	f (10^{12} Hz)
Violet	400	750
Indigo	425	706
Blue	470	638
Green	550	545
Yellow	600	500
Orange	630	476
Red	665	451

- travels through a single uniform medium (e.g., air at constant temperature, water at constant temperature and pressure, glass) in a straight line
  - this is the working principle behind the human eye and pinhole cameras

White light…

- light from the sun in the full spectrum of visible light
- reaches the surface of Earth through an "optical window" in the atmosphere

- blue is scattered more in the atmosphere causing the sky to appear blue
- in human eyes – rods sense brightness and cones give signals for red, green, and blue light
- the sensitivities of red and green cones are very similar thus the brain only interprets a color as "red" when the signal from red cones is twice as strong as green cones
- when the functioning of red and green cones is impaired, causing a person to be unable to distinguish red from green, that person is said to be "color blind"
- the brain interprets other colors by the combination of the intensity of signals from the three types of cones
- an equal signal from all three types of cones is interpreted as "white" light

Optical phenomenon

Refraction is the change in direction of light due to a change in its speed. This is most commonly observed when light passes from one medium to another. The index of refraction, n, gives the speed of light in the medium relative to the speed of light in a vacuum, which can be used to predict the angle the light will bend.

$$n = \frac{c}{v_{\mathrm{p}}}$$

Examples
- Light through glass
- Fish in water
- mirages

Dispersion is the phenomenon in which the velocity of light depends on its frequency. Media having such a property are termed *dispersive media*.

Examples
- Prisms
- diamonds
- rainbows

Diffraction is normally taken to refer to various phenomena which occur when light encounters an obstacle. It is described as the spreading out of light past small openings. The spreading is described by

$$S = \frac{L}{D} R$$

Where S is the spread, L is the wavelength, D is the diameter, and R is the distance from the opening. This equation also describes the blurring of objects far away from a camera, such as in a spy satellite, do to the spread of the light coming from them.

Polarization is a property of light waves that describes the orientation of their oscillations. Polarization describes the orientation of the oscillations of light waves in the plane perpendicular to the wave's direction of travel. The oscillations may be oriented in a single direction, either vertically or horizontally by polarizing filters.

Reflection is the change in direction of a wavefront at an interface between two different media so that the wavefront returns into the medium from which it originated. Common examples include the reflection of light, sound and water waves. The *law of reflection* says that for smooth surfaces, the angle at which light is incident on the surface equals the angle at which it is reflected.

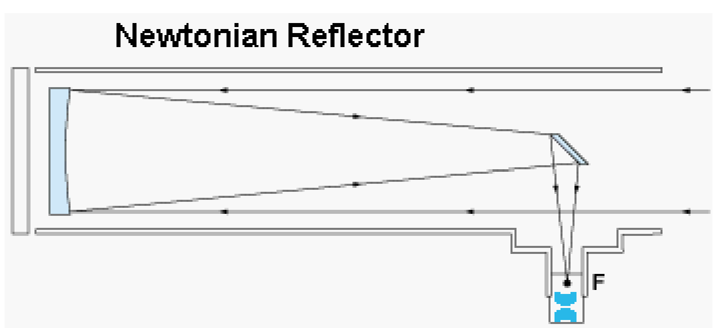
Lenses are optical devices which transmit and refract light, converging or diverging the light beam**.** **Convex** lenses focus light to a point and **concave** lenses spread out a beam of light

Focal length of a lense is a measure of how strongly it converges (focuses) or diverges (diffuses) light. A lense with a shorter focal length has greater optical power than one with a long focal length.

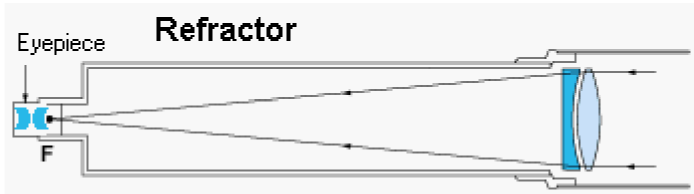
Eyeglassses, magnifying glasses, camera lenses, binoculars, telescopes, microscopes, etc. are made from single lenses or multiple lenses and mirrors in different configurations to achieve the resolution of an image that can be viewed by humans

Below are examples of telescope and microscope configurations, just as examples to show that they are made up of multiple lenses and/or mirrors in different configurations

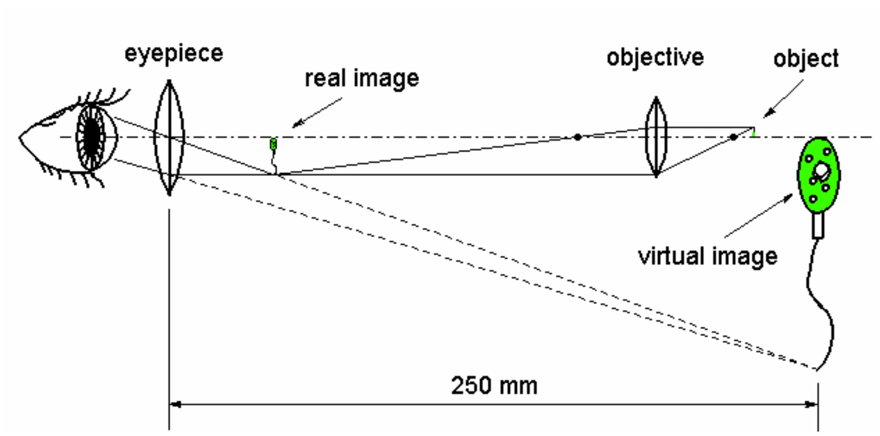
Newtonian (Reflecting) Telescope



Galilean (Refracting) Telescope


Refractor
Eyepiece
F

Microscope


eyepiece
real image
objective
object
virtual image
250 mm