

Introduction to Optics

The Pasco Optics System.

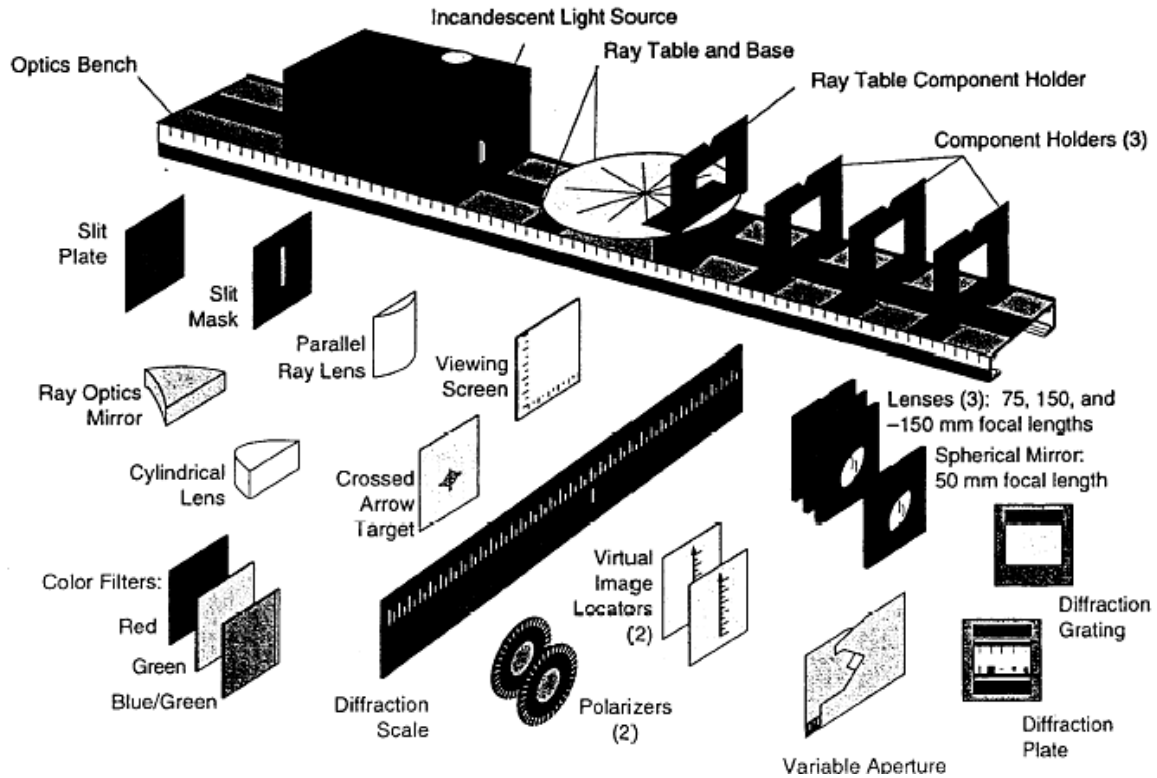


Figure 1 (Courtesy of PASCO)

Setting up the Equipment

The Optics Bench

The optics bench is shown in Fig. 2 along with the light source, component holder and ray table base. Proper alignment of the components requires the edges of the components to be flush with the raised edge of the optics bench.

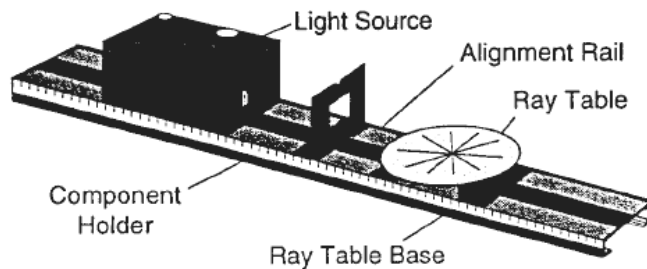


Figure 2 (Courtesy of PASCO)

Incandescent Light Source

The light source is shown in Fig. 3. The light source should be plugged into a grounded 110V outlet. To turn on the light source flip the On Switch. The filament knob moves the light bulb from side to side inside the housing.

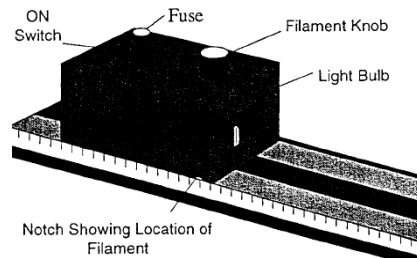


Figure 3 (Courtesy of PASCO)

Component Holders and Components

The optics system includes three component holders for the bench and one component holder for use on the ray table. The notches on the top of the holders are used for aligning the components. The notches on the base of the holders are to mark the position of the component on the bench for distance measurements. Both notches are shown in figure 4.

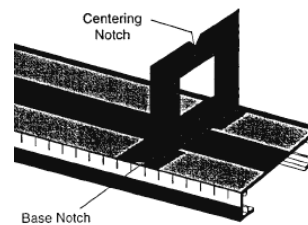
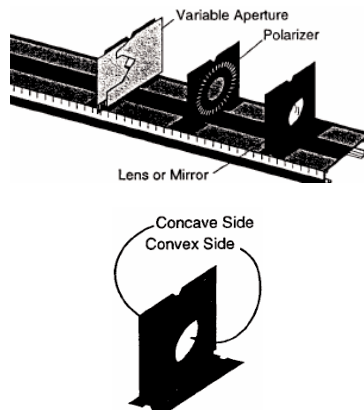


Figure 4 (Courtesy of PASCO)

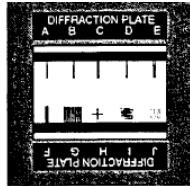
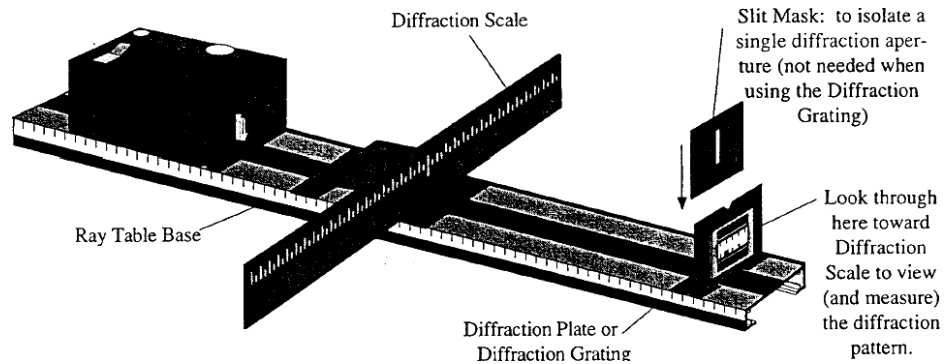


When using the variable aperture, polarizer, lenses or mirrors, use the centering notch to align the components on the optical axis of the bench. The notch can also be used with the polarizer to measure the angle of polarization. The spherical mirror is silvered on both sides for use as a concave or convex mirror. Fig 5.

Figure 5 (Courtesy of PASCO)

Diffraction Experiments

When setting up the equipment for diffraction experiments one may use the *diffraction plate* or the *diffraction grating*. If using the diffraction plate, use the slit mask on the other side of the component holder to illuminate only one of the single diffraction apertures. When looking through the aperture or grating, the diffraction pattern will be superimposed over the diffraction scale. This will be useful to make accurate measurements of the diffraction pattern geometry. Dimensions of the apertures in the diffraction plate are provided in Fig 6.



Pattern	No. Slits	Slit Width (mm)	Slit Spacing center-to-center (mm)
A	1	0.04	
B	1	0.08	
C	1	0.16	
D	2	0.04	0.125
E	2	0.04	0.250
F	2	0.08	0.250
G	10	0.06	0.250
H	2 (crossed)	0.04	
I	225 Random Circular Apertures (.06 mm dia.)		
J	15 x 15 Array of Circular Apertures (.06 mm dia.)		

Figure 6 (Courtesy of PASCO)

Basic Ray Optics Setup

Align the ray table base along the rail of the optics bench. The ray table itself sits upon the ray table base. The ray table base is slanted and should be sloping downward in a direction toward the light source on the optics bench. The ray table has a rotational scale and a linear scale to make use of either measurement.

The slit plate attached to a component holder should be placed between the light source and the ray table aligned along the rail of the optics bench. The distances between the components on the optics bench can be varied to yield clear lines on the ray table. Another component holder on the ray table can be used to hold the viewing screen, the polarizer, or other various components. See Fig. 7.

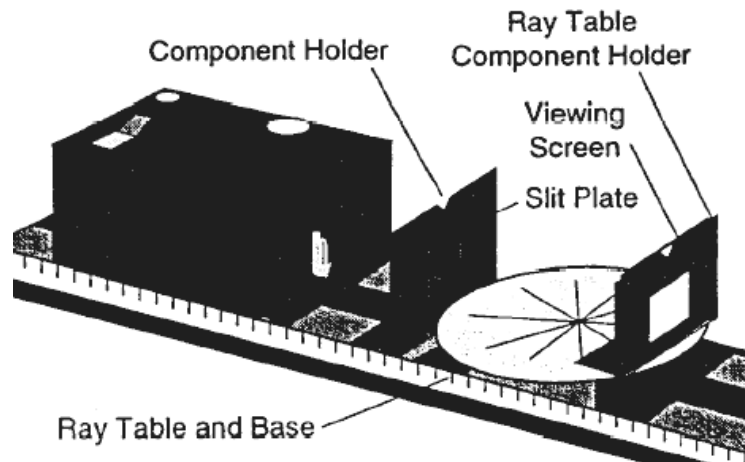


Figure 7 (Courtesy of PASCO)

Single Ray Setup

To perform experiments using a single ray use the slit mask to block all but the desired ray. For measurements using the rotational scale adjust three parameters as needed (Fig. 8.).

1. The lateral position of the slit plate on the component holder,
2. The position of the light source filament with respect to the optical axis,
3. The rotation of the ray table.

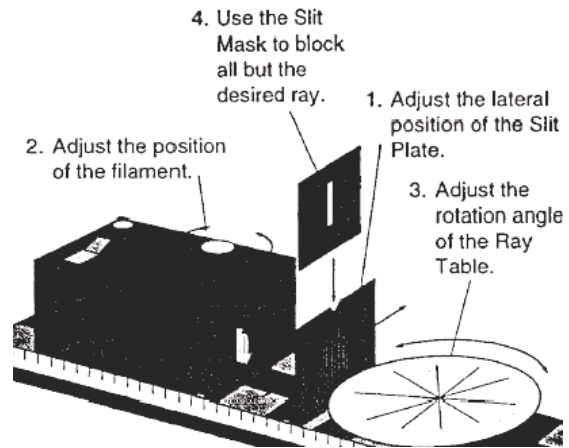


Figure 8 (Courtesy of PASCO)

Parallel Ray Setup

Parallel rays are obtained by placing the parallel ray lens between the light source and the ray table as in Fig. 9. The parallel lines of the ray table can be used as a reference. The longitudinal position of the lens should be adjusted until the rays are parallel.

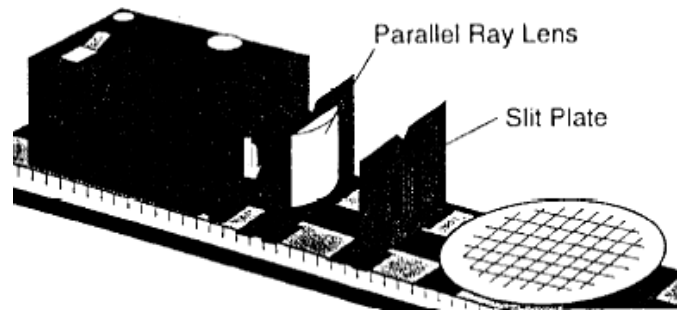


Figure 9 (Courtesy of PASCO)

The Electromagnetic Spectrum/Electromagnetic Waves

- E/M waves are disturbances that travel through space
- Consist of particles and waves
- All e/m waves travel at the speed of light (3×10^8 m/s) in free space, c
- All e/m waves transport energy (electromagnetic energy)
- The relationship between speed, frequency and wavelength in free space:
 $c = \lambda f$
- The relationship between energy and frequency or wavelength: $E = hf = h \frac{c}{\lambda}$
- Note that decreasing wavelengths \rightarrow increasing energy
- Longer wavelengths \rightarrow lower frequency
- E/M waves reflect, refract, scatter, diffract, interfere, and may be polarized

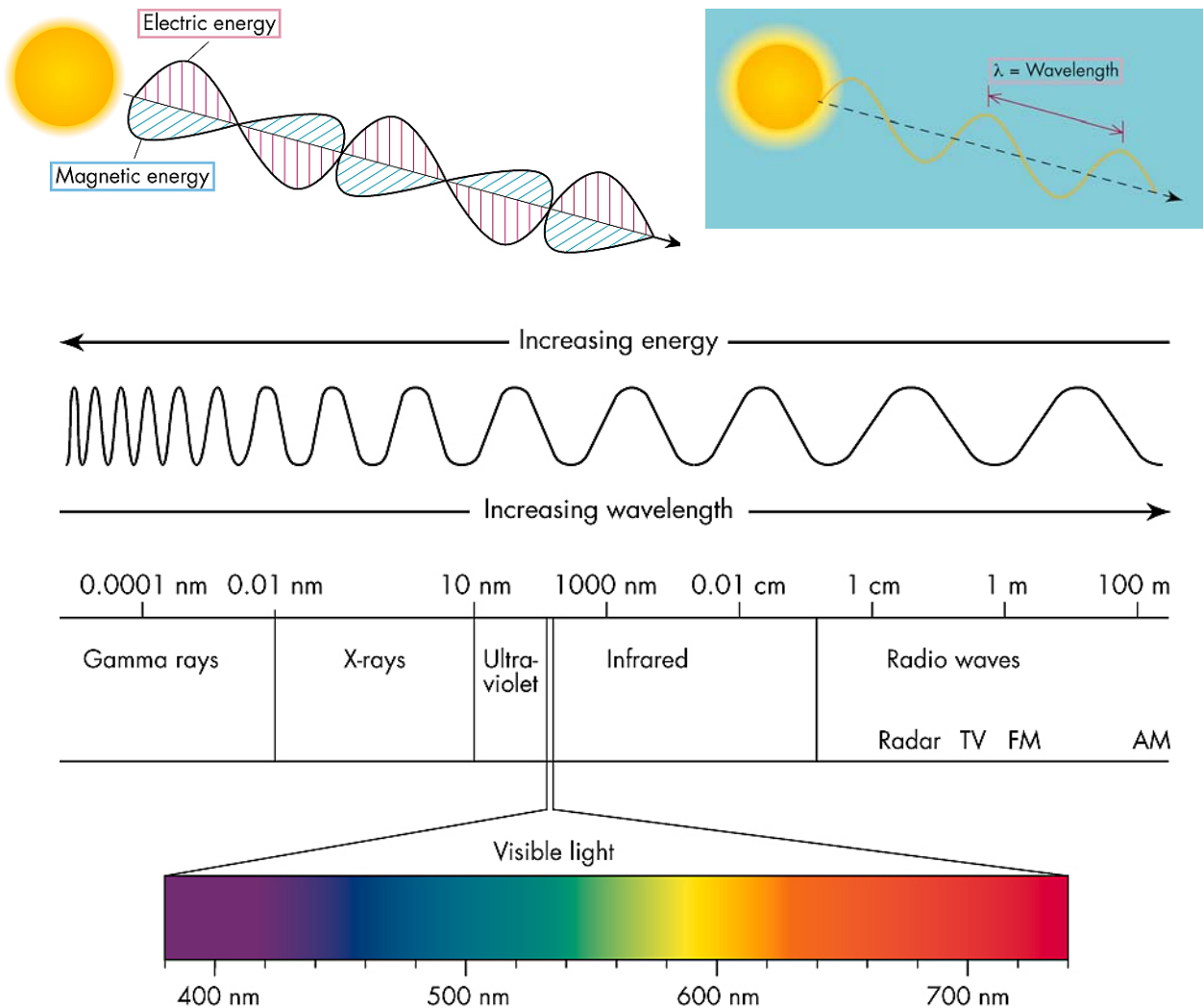


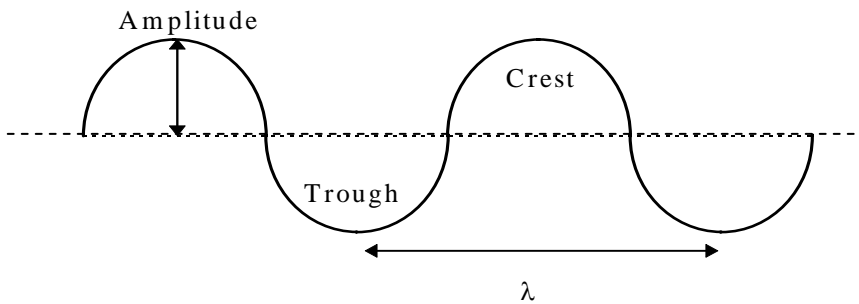
Figure 10 (Courtesy of Thomas Army)

Historical Figures and Their Contributions to Theories of Light

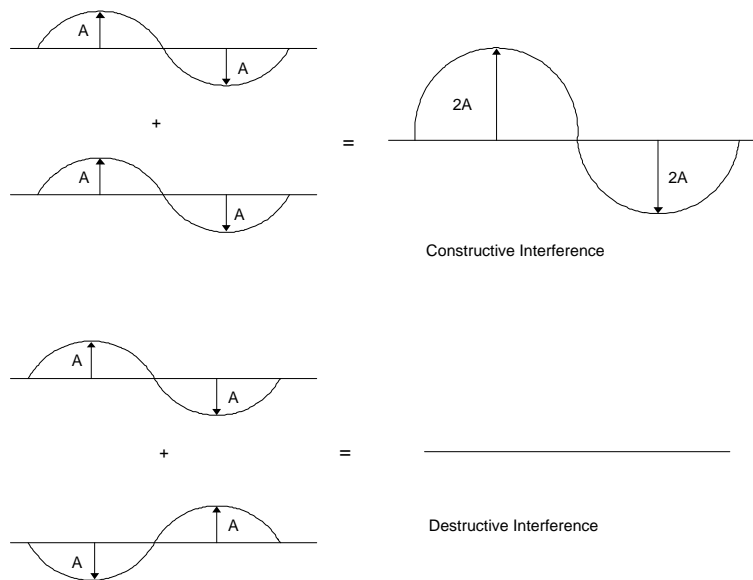
- Newton - corpuscular theory
- Huygens - wave theory
- Young - interference
- Maxwell - E/M equations
- Michaelson & Morley - luminiferous ether
- Einstein - photons

Physical Attributes of Light

- Visible light exists between 400 - 700 nanometers (10^{-9}), 0.4 - 0.7 microns (10^{-6}), 4000 - 7000 Angstroms (10^{-10})
- White light consists of all frequencies in the visible range combined
- Wavelength - peak to peak distance
- Amplitude - $\frac{1}{2}$ of the distance from peak to trough
- Frequency - number of oscillations per second



- *interference* - combining e/m waves together in such a manner as to cause constructive (bright) or destructive (dark) patterns to result.



- *diffraction* - bending of light or any e/m waves as they pass through narrow openings or around sharp corners. Explained by *Huygen's Theory* (below).
- *reflection* - a form of scattering that may be described with a simple geometric relationship, i.e. angle of incidence equals angle of reflection (The Law of Reflection).
- *scattering* - what happens, in general, when light or any e/m waves interact with matter.
- *polarization* - orientation of e/m fields in space

- *refraction* - the change of speed and direction that occurs when light goes from one medium to another. Refraction of white light, which contains all wavelengths from 400 to 700 nanometers results in *dispersion*.

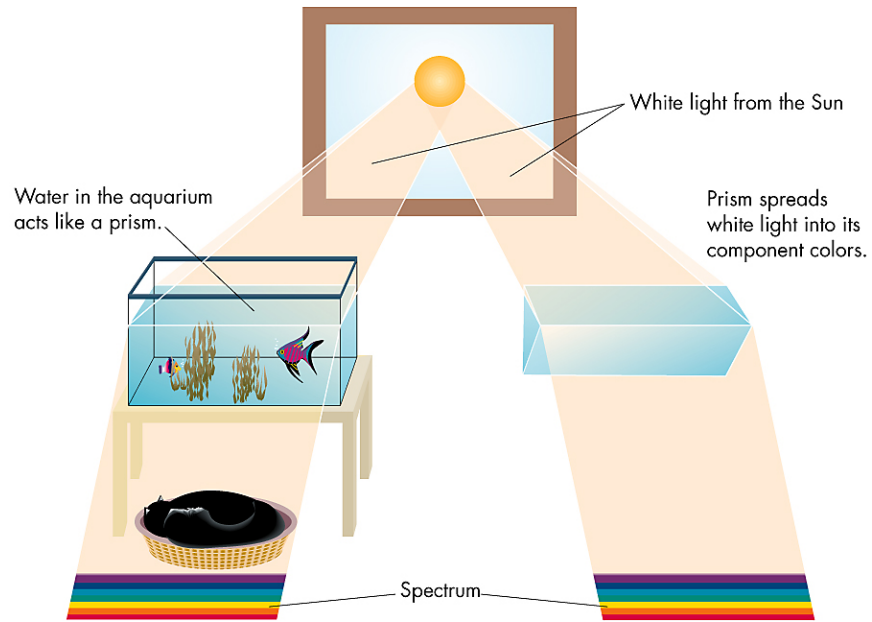
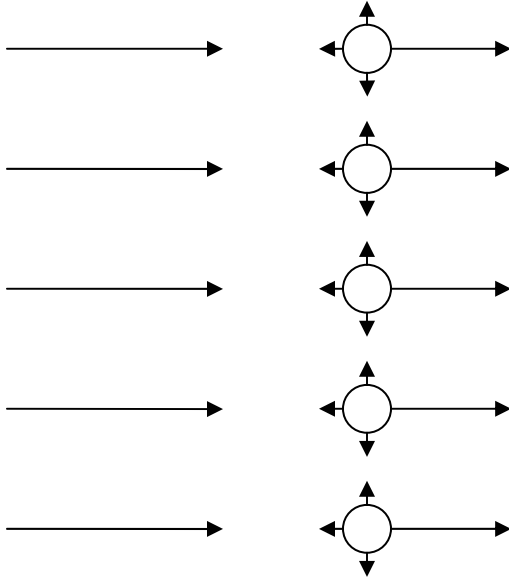


Figure 11 (Courtesy of Thomas Arny)

How Light Interacts with Matter

Light is propagated through any dense medium (air, water, etc.) primarily by scattering. When light encounters a change in medium (falls on a surface, for instance) it may be absorbed, scattered or reflected.

Light travels through any dense medium via scattering



- Christian Huygens was the first to propose that light was a wave.
- Light waves traveling together through space or any dense medium form *wavefronts*.
- Any point on a wavefront is capable of acting as a new source of the wave. This is known as **Huygens Theory** and may be used to explain *reflection, refraction, diffraction* and *interference*.

Consider Earth's sky. On a clear day the sky is blue at noon and reddish or yellow near sunrise and sunset. On days when there is a lot of particulate matter in the atmosphere (water vapor, pollutants, etc.) the sky appears milky white.

Can you use Huygens' Theory and your knowledge of visible light to explain this?

Natural Occurrences of Optical Phenomena

Reflection

- Glitter Path
- Rainbows (total internal reflection)

Refraction

- Twilight
- Stars "twinkle"
- Rainbows (dispersion)
- Mirage

Superior Mirage

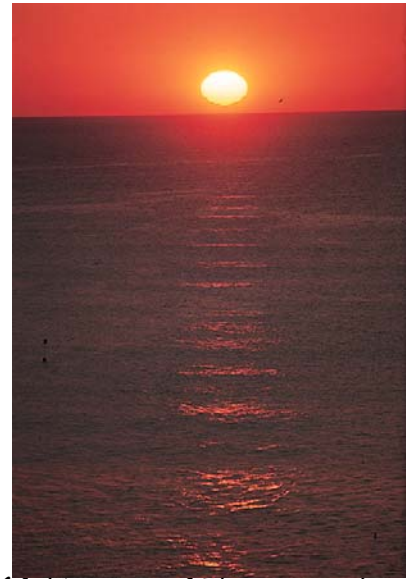
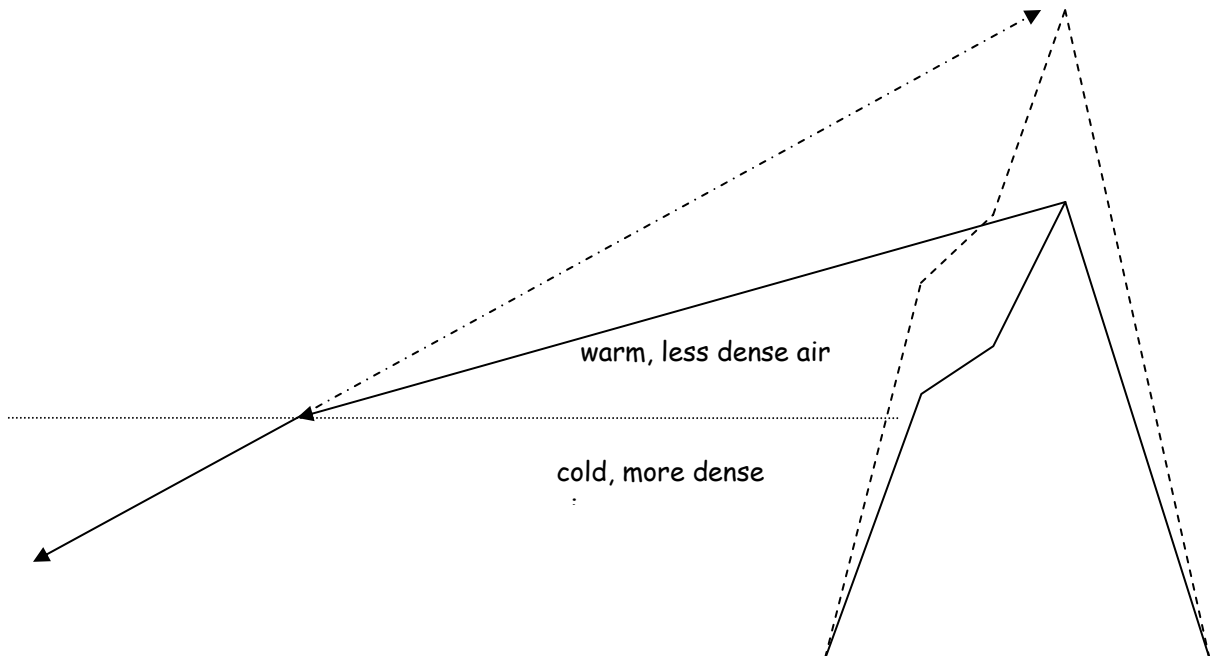
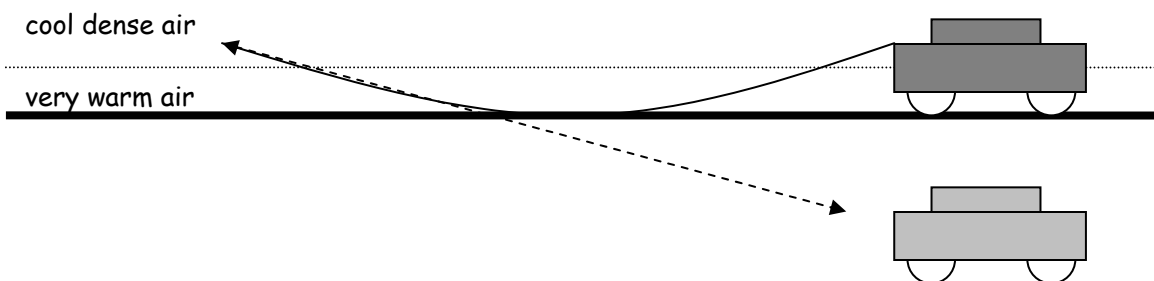


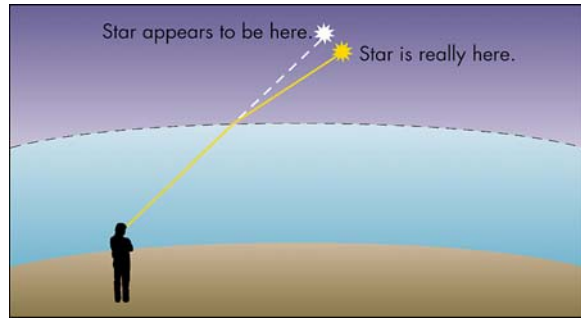
Figure 11 (Courtesy of Thomas Army)



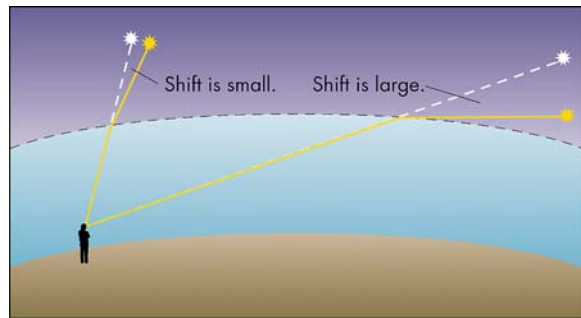
Inferior Mirage



Refractory phenomena



Twilight



The "twinkle" of stars

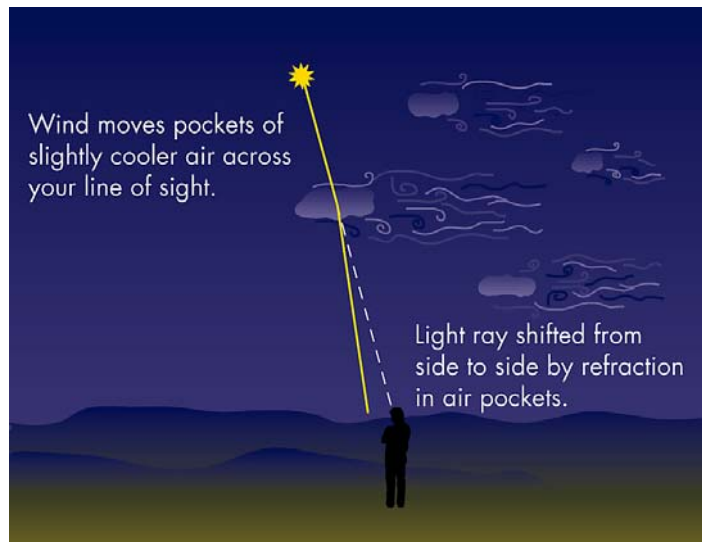


Figure 12 (Courtesy of Thomas Arny)

Diffraction

- Corona
- Glory
- Heiligenschein
- Some Halos

Scattering

- Blue skies
- Red sunsets

Interference

- Supernumerary Arcs (rainbows)

Polarization

- Light at high altitudes is highly polarized
- Reflected light may be highly polarized

Origin of Light

Visible, ultraviolet and infrared light originates from electronic transitions in atoms. Gamma rays originate from similar events in the nuclei of atoms. X rays may form in any of several ways but most commonly from the rapid acceleration of atoms. At the other end of the spectrum, radio waves result from the oscillations of large numbers of charged particles.

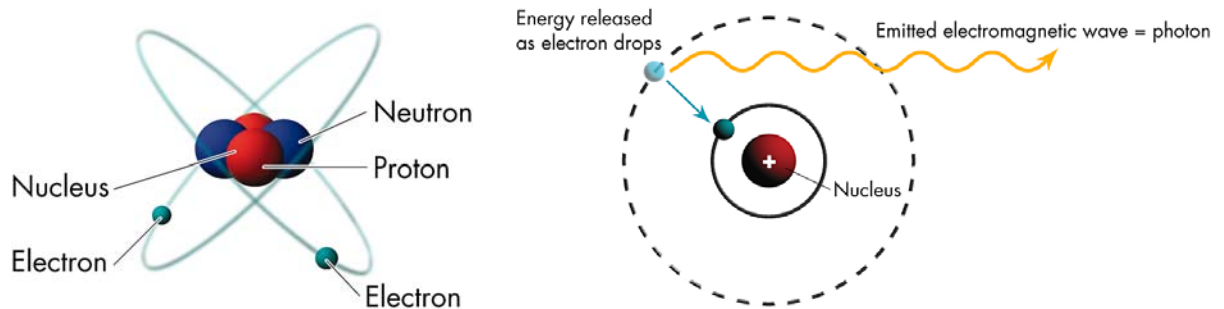


Figure 13 (Courtesy of Thomas Arny)