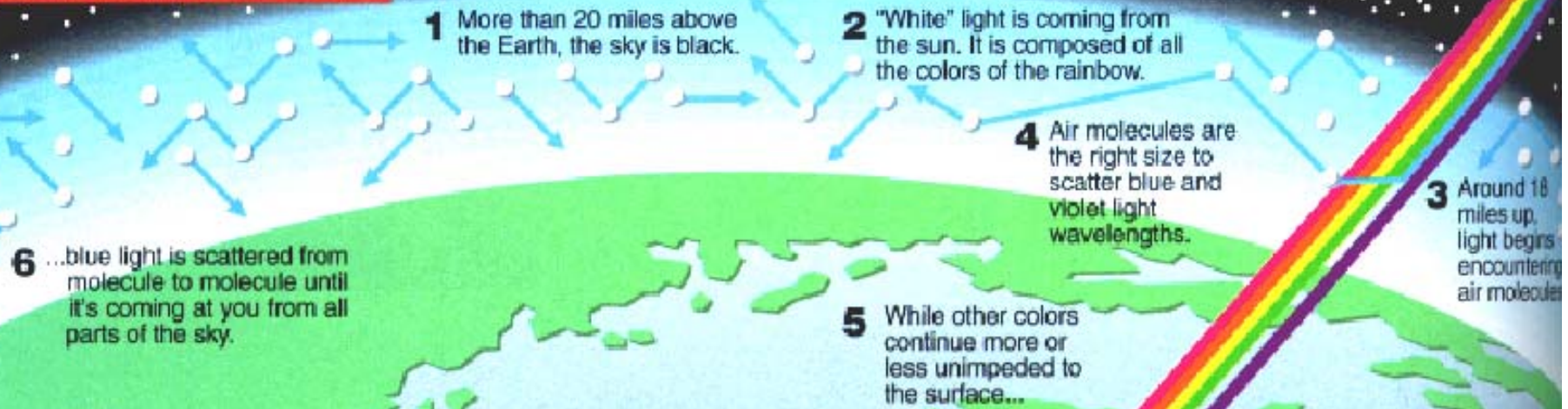


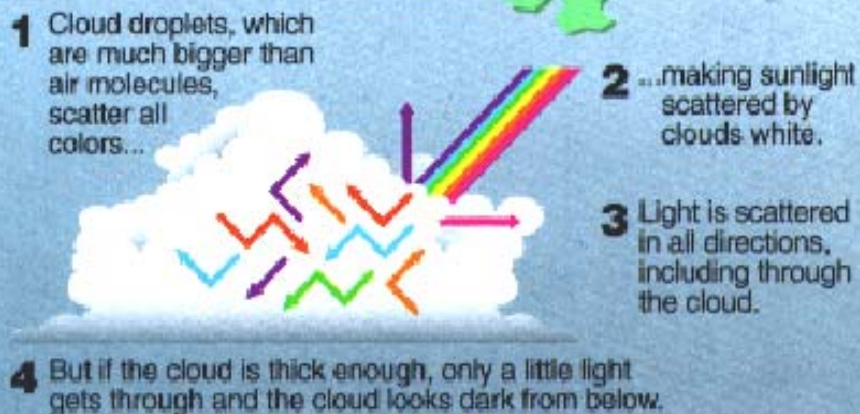
Lecture 31 Atmospheric Optics I

TWB, p. 152

WHY SKIES ARE BLUE

- 
- The diagram illustrates the process of light scattering in the atmosphere. A rainbow spectrum of light enters from the right, representing sunlight. As it moves left towards the Earth's surface, it is shown being dispersed into its constituent colors. Blue and violet light are shown being scattered more widely and frequently by small air molecules, indicated by many small arrows pointing in various directions. Other colors like red and yellow are shown continuing more directly towards the surface with fewer scattering events. The Earth's surface is depicted as a green landmass and blue ocean.
- 1 More than 20 miles above the Earth, the sky is black.
 - 2 "White" light is coming from the sun. It is composed of all the colors of the rainbow.
 - 3 Around 18 miles up, light begins encountering air molecules.
 - 4 Air molecules are the right size to scatter blue and violet light wavelengths.
 - 5 While other colors continue more or less unimpeded to the surface...
 - 6 ...blue light is scattered from molecule to molecule until it's coming at you from all parts of the sky.

WHY CLOUDS ARE WHITE

- 
- The diagram shows a white cloud with a rainbow spectrum of light entering from the right. Multiple arrows of different colors are shown reflecting off the surface of the cloud droplets in many different directions, representing the scattering of all wavelengths of light. The Earth's surface is visible at the bottom.
- 1 Cloud droplets, which are much bigger than air molecules, scatter all colors...
 - 2 ...making sunlight scattered by clouds white.
 - 3 Light is scattered in all directions, including through the cloud.
 - 4 But if the cloud is thick enough, only a little light gets through and the cloud looks dark from below.

WHY SUNSETS ARE RED

- 
- The diagram shows a horizontal path of light from the sun (represented by a yellow circle) to the Earth's surface. The light path is a gradient bar transitioning from yellow/orange on the left to red on the right. The Earth's surface is shown at the bottom right. The path is longer than in the previous diagrams, indicating a greater distance through the atmosphere.
- 1 At sunset and sunrise, sunlight is traveling farther through the atmosphere.
 - 2 The longer trip means more and more light at the blue end of the spectrum is scattered.
 - 3 This leaves red, yellow, orange light to reach our eyes or reflect off clouds.

- White light is mixture of all colors in rainbow.
- The color of an object depends on the wavelengths of light which the object best reflects or scatters.
- Light scatters more off particles closer in size to its wavelength:

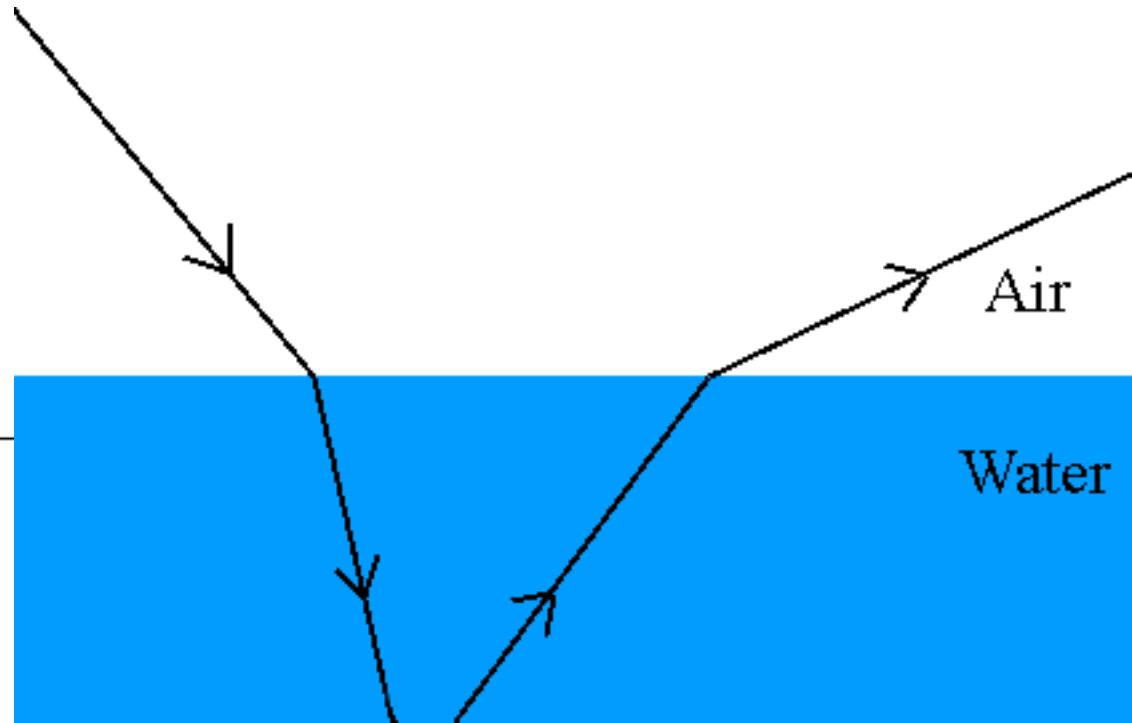
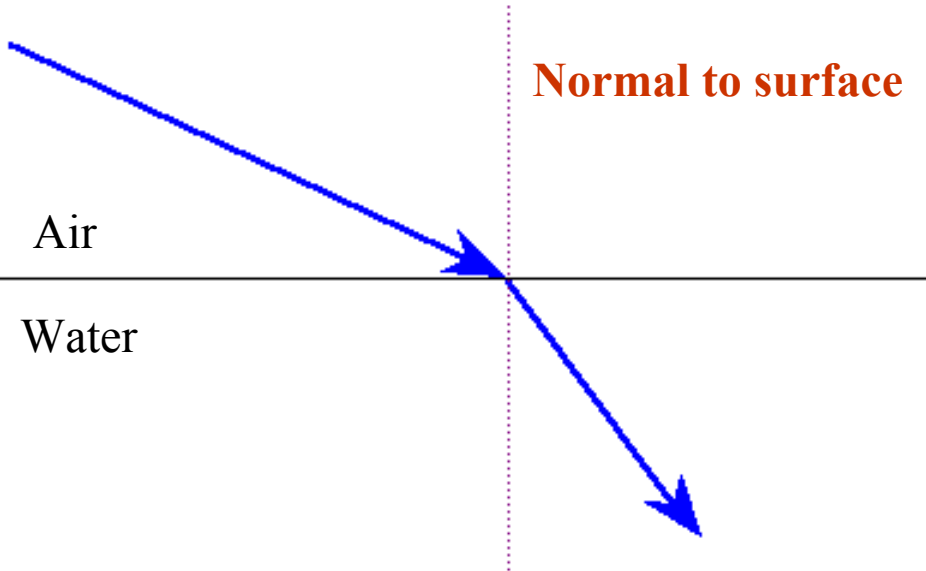
Air molecules	0.001-0.002 μm across
Blue light	0.4 μm wavelength
Red light	0.7 μm
Pinatubo Aerosols	1 μm across
Cloud drops	20 μm across
- Cloud drops scatter all wavelengths nearly equally, so clouds look white.
- More short wavelength blue light is scattered by tiny air molecules than long wavelength red light. This light, scattered in all directions, makes sky appear blue.
- If the sun is low above horizon, sunlight passes through lots of atmosphere, so the unscattered light in the sun's beam now is mainly the yellow, orange, red of sunsets (can also reflect off clouds).
- Large aerosol particles can efficiently scatter red light to make red dawn, dusk (Pinatubo, 1991).

Refraction

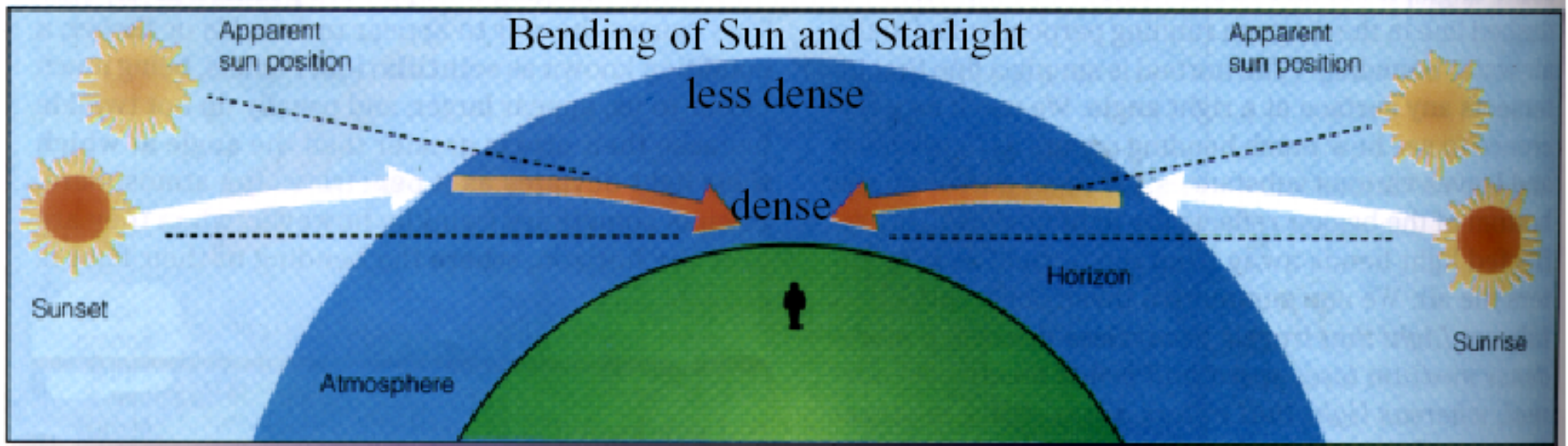
Light *refracts* (bends) toward a denser substance .

Refraction

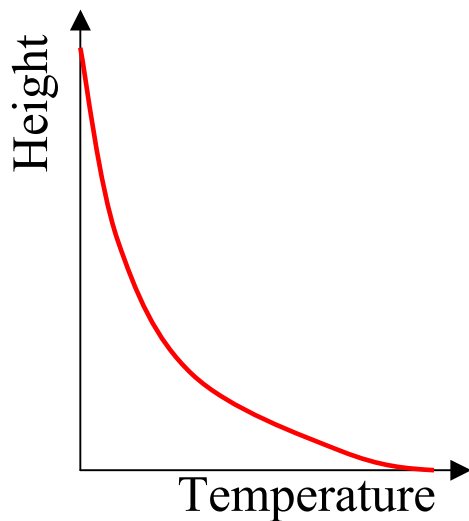
Light bends toward the normal when entering water.
Amount of bending depends on material, wavelength, and incident angle



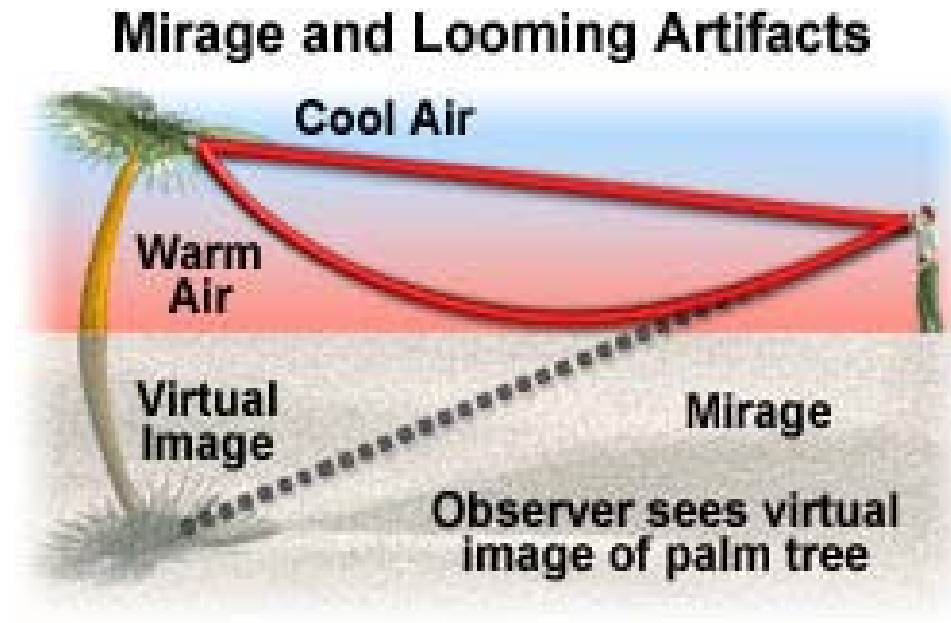
Atmospheric Effects of Refraction



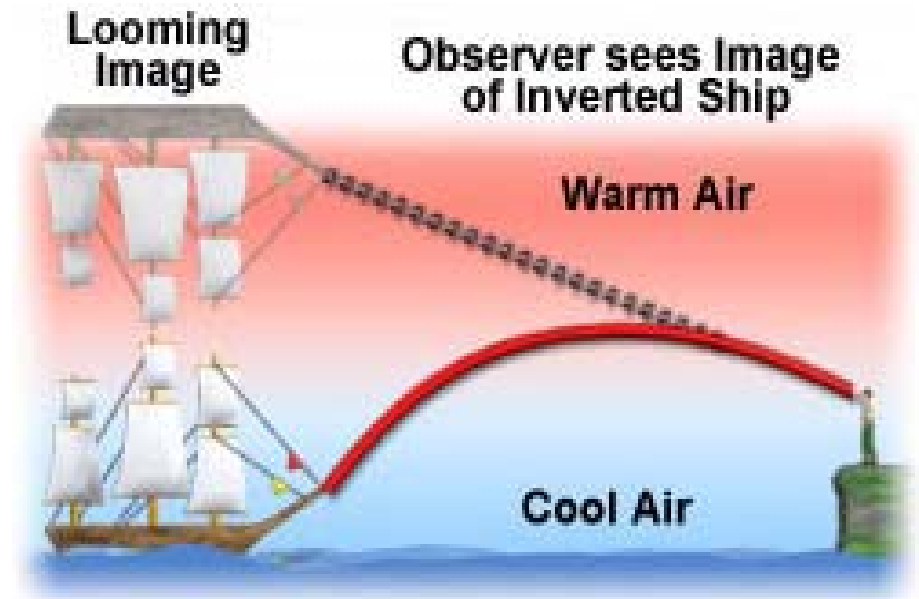
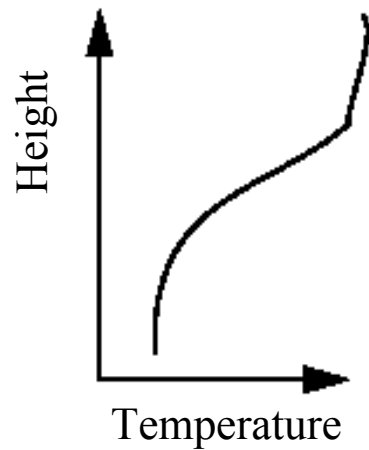
EOM Fig. 15.11. The bending of the sun's rays by the atmosphere causes the sun to rise about two minutes earlier and set about two minutes later than it otherwise would.



Temperature profile
above sand



Fata Morgana 'Superior' Mirage



King Arthur's half-sister, Fata Morgana in Italian, lived in a crystal palace beneath the water and could build fantastic castles from thin air.



Fata Morgana



Plate 7-4. Fata morgana mirage showing an apparent wall over the Arctic Ocean ice. (Photographed at Pt. Barrow, Alaska, by the author)



Plate 7-5. Fata morgana mirage showing columns and spires over the Arctic Ocean. (Photographed by the author)

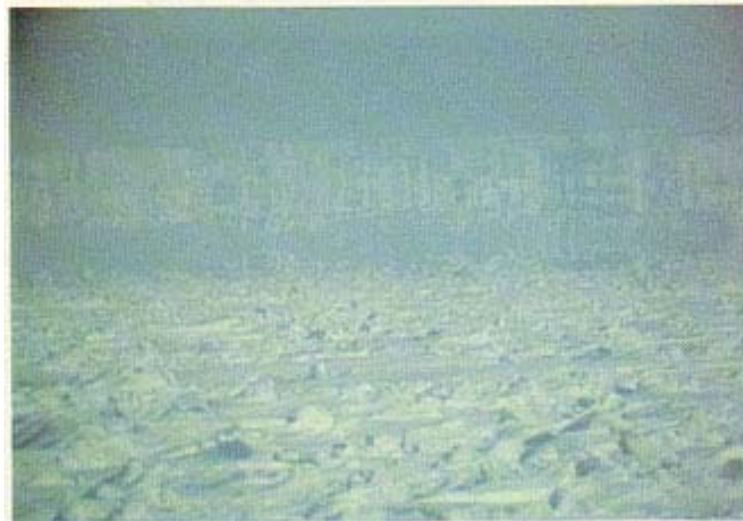


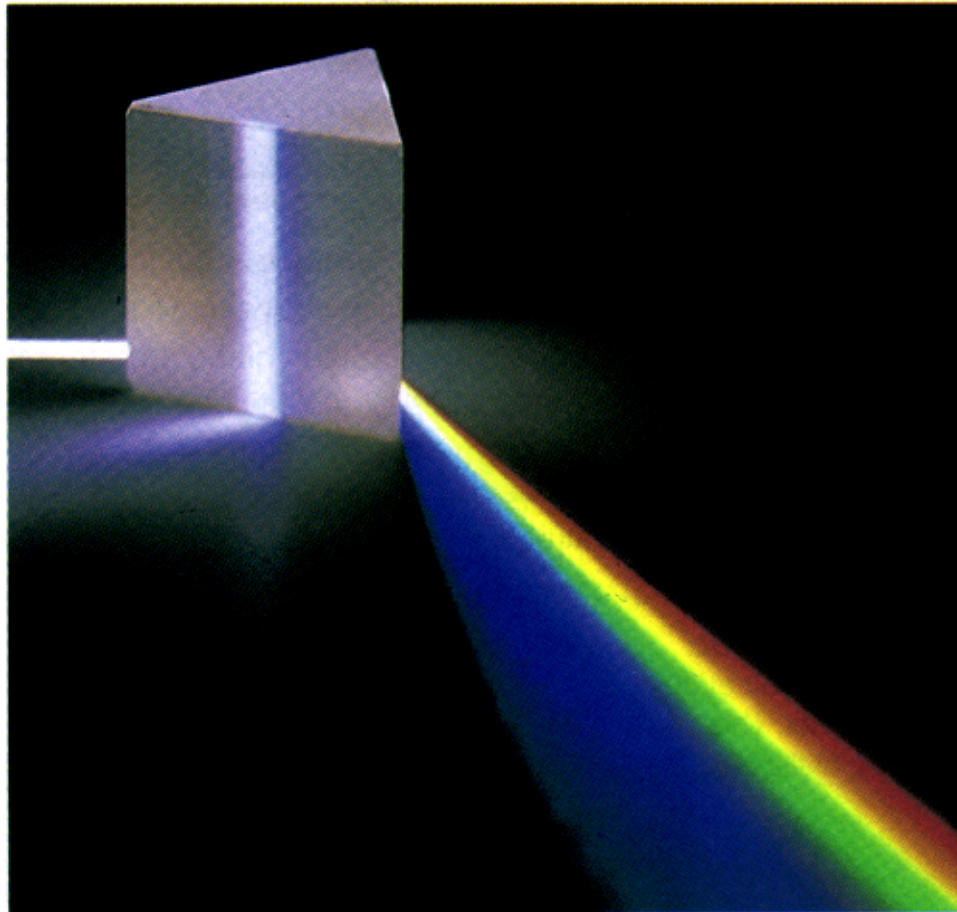
Plate 7-6. Fata morgana mirage showing an apparent detached wall over the Arctic Ocean. (Photographed by the author)



Plate 7-7. Another variation of the fata morgana mirage over the Arctic ice. (Photographed by the author)

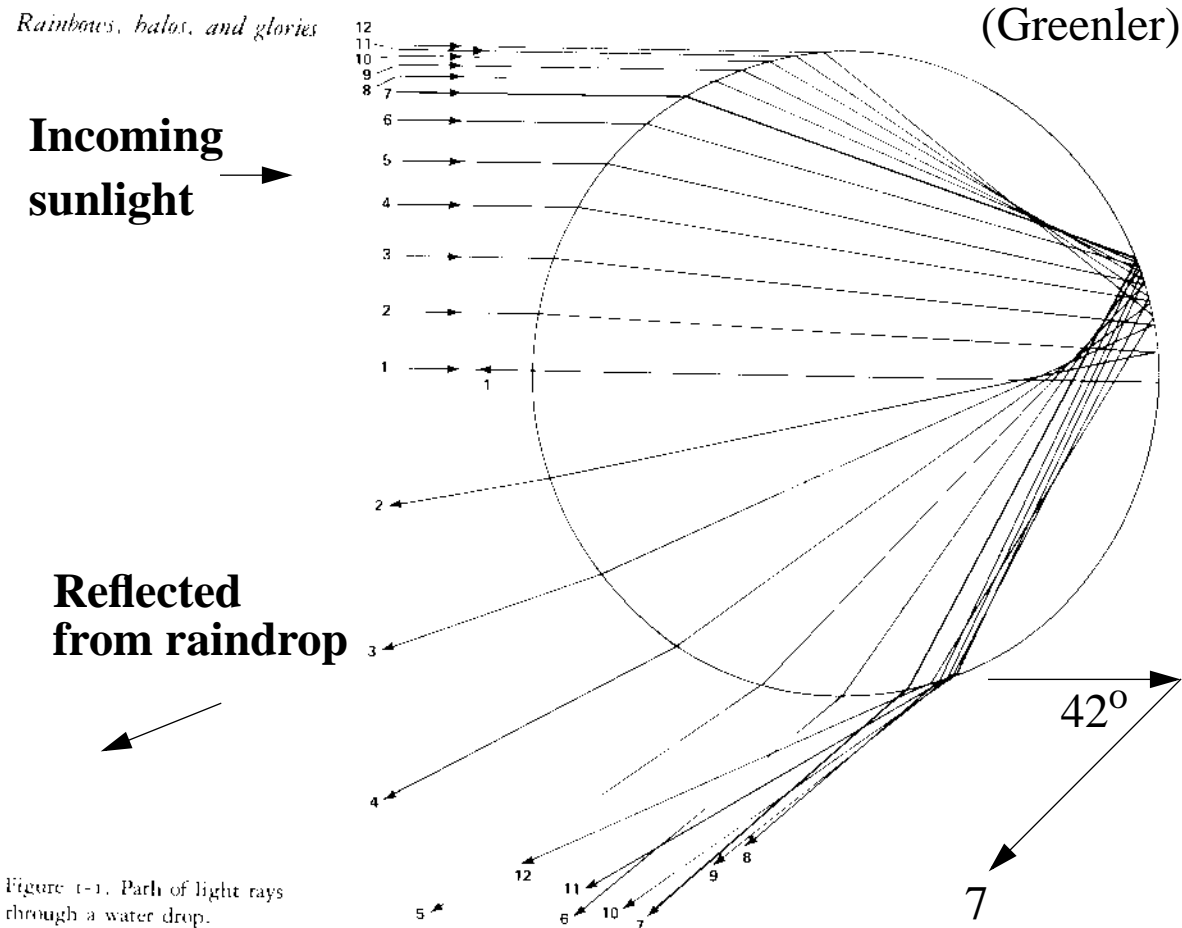
Dispersion

Blue (shortest wavelength) light refracts slightly more than red light, so refraction can *disperse* light into its component colors.



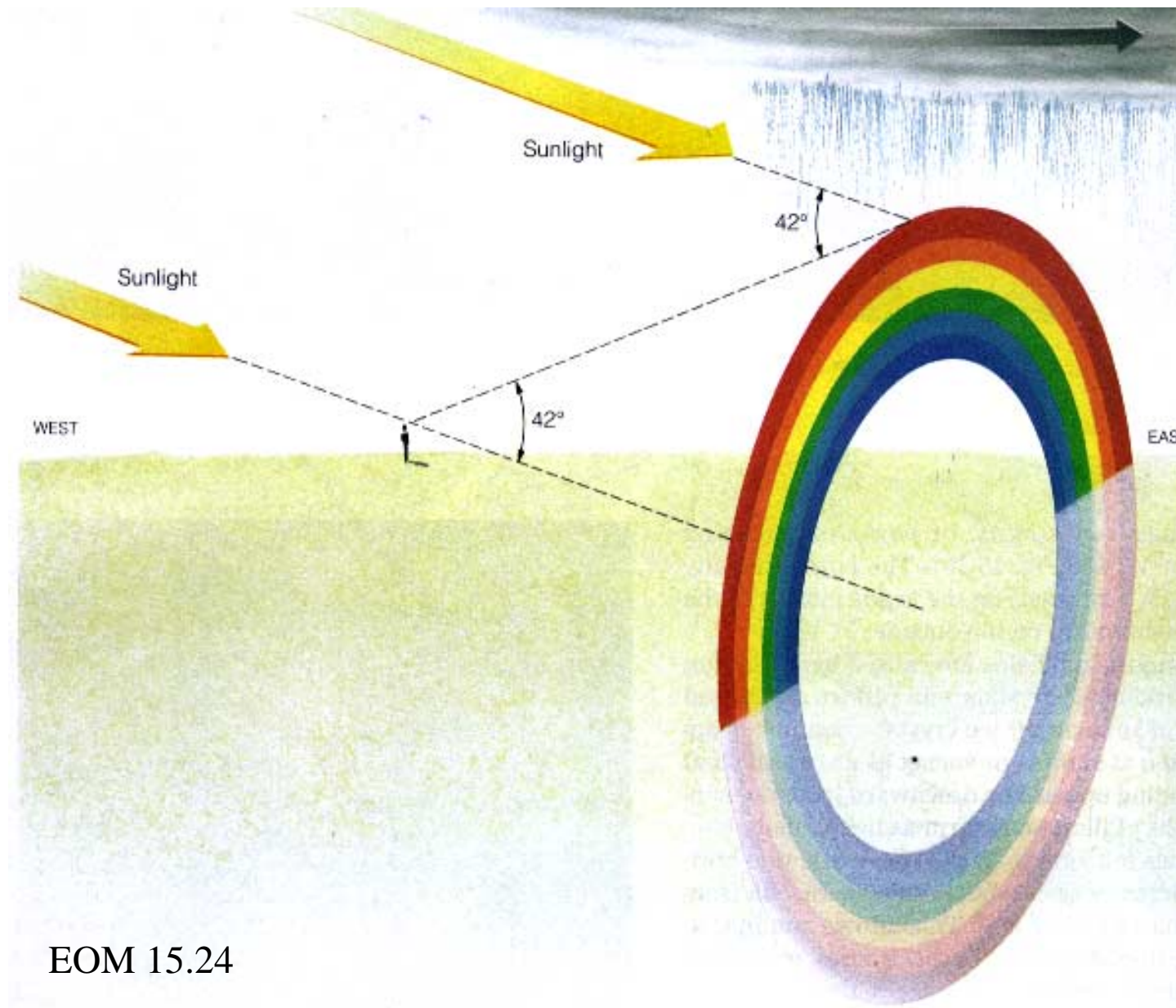
EOM 15.19

Rainbows



- Rainbows are formed when sunlight reflects off the inside of raindrops.
- Reflection angle depends on how obliquely beam hits drop, but is nearly 42° for many rays near the Descartes ray (7), which reflects at largest angle.

Position of a Rainbow



EOM 15.24