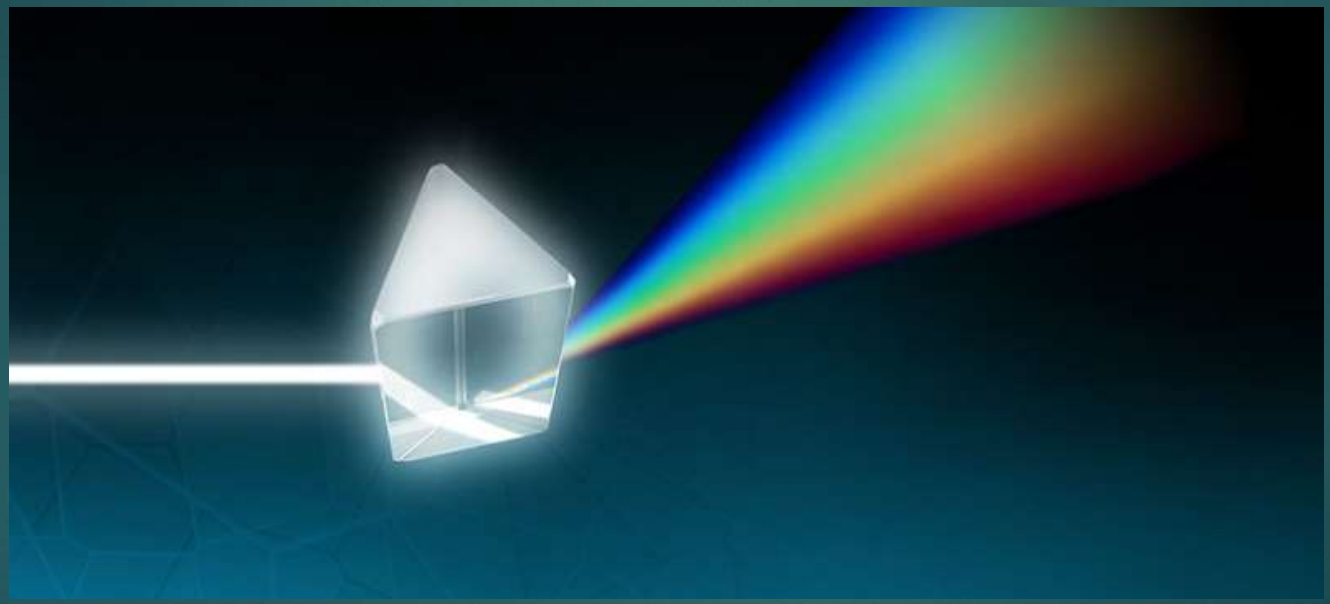
Refraction

PHYSICS 112: LIGHT LEARNING TARGET 3 (LLT3)

Refraction: The change in direction of light as it enters a different medium



Refraction

- Light changes direction, when entering a different medium at an angle, because it is a wave.
  - The new angle within the medium is called the refracted angle.

Index of Refraction

- It is represented by the variable ***n***, and is a ratio of the speed of light in a perfect vacuum to that of the medium it is in.

$$n = \frac{c}{v}$$

- The number will always be greater or equal to 1, and it measures by what factor light slows down in a medium.

Index of Refraction

Substance	Index of Refraction (n)
vacuum	1.00000
gases at 0°C, 1.013×10^5 Pa	
hydrogen	1.00014
oxygen	1.00027
air	1.00029
carbon dioxide	1.00045
liquids at 20°C	
water	1.333
ethyl alcohol	1.362
glycerin	1.470
carbon disulfide	1.632

Substance	Index of Refraction (n)
solids at 20°C	
ice (at 0°C)	1.31
quartz (fused)	1.46
optical fibre (cladding)	1.47
optical fibre (core)	1.50
Plexiglas™ or Lucite™	1.51
glass (crown)	1.52
sodium chloride	1.54
glass (crystal)	1.54
ruby	1.54
glass (flint)	1.65
zircon	1.92
diamond	2.42

Index of refraction: Mathematical Analysis

$$n = \frac{c}{v}$$

- Example 1:
  - The speed of light in a solid is 2.50×10^8 m/s. Calculate the solid's refractive index.
- Example 2:
  - Calculate the speed of light in glycerin.

Index of refraction: Mathematical Analysis

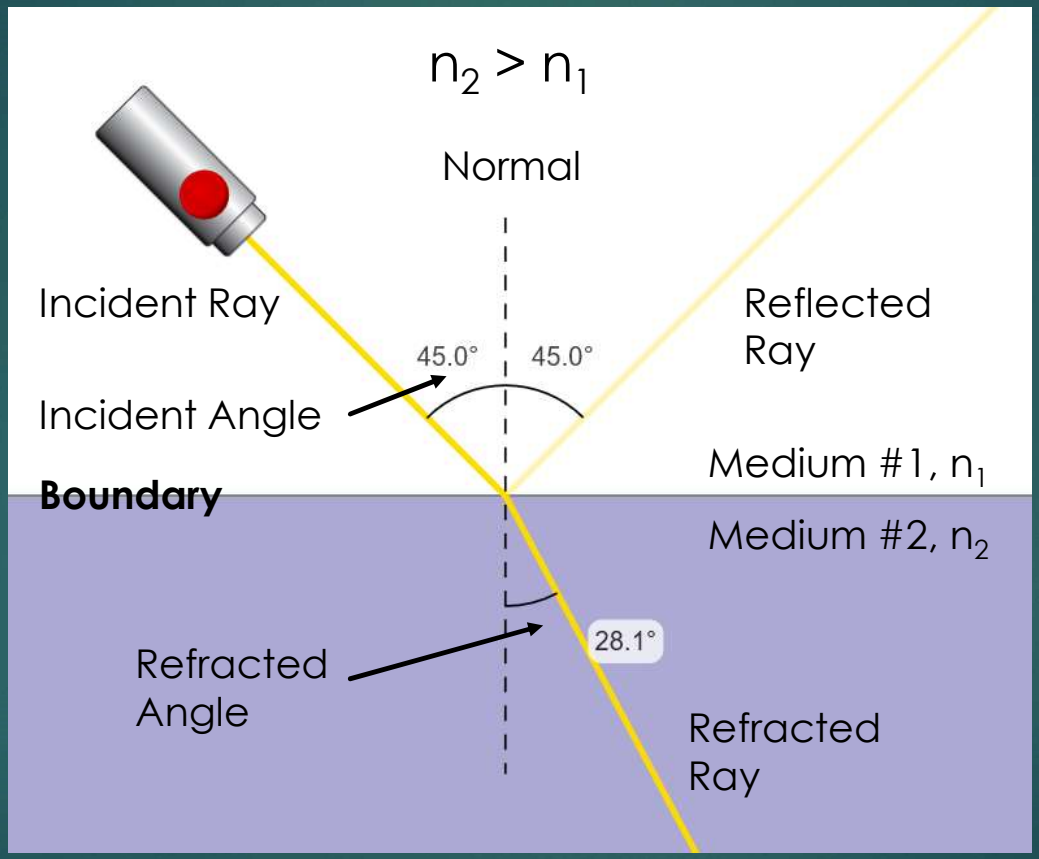
$$n = \frac{c}{v}$$

- Example 3:
  - Calculate the wavelength of yellow light in Plexiglas if its frequency is 7.05×10^{14} Hz.
- Example 4:
  - A ray of light is reflected within the cuts of a diamond for 1.5 seconds. Calculate the distance traveled by light in that time.
- Practice Problems #s 1 – 10.

Investigating Refraction

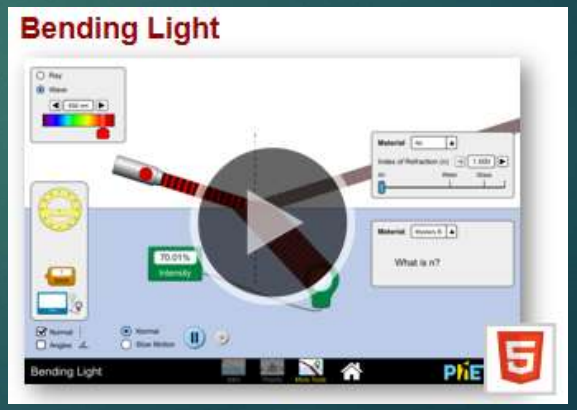
- Using the light boxes and available glass blocks, identify:
  - Light changing direction as it goes from a fast to slow medium.
  - Light changing direction as it goes from a slow to fast medium.
  - Is there a maximum angle of refraction in the slower medium?
  - Is there a maximum angle of incidence in the slower medium?
  - Can you make a rainbow?

Refraction Diagram & Terms



Angle of Refraction

- Less than the angle of incidence when light travels in to a slower moving, larger ***n*** value, medium.
- Greater that the angle of incidence when light travels to a faster moving, lower ***n*** value, medium.



Snell's Law

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

- 1 = incident, or where light begins in the problem.
- 2 = refracted, or where light ends in the problem.

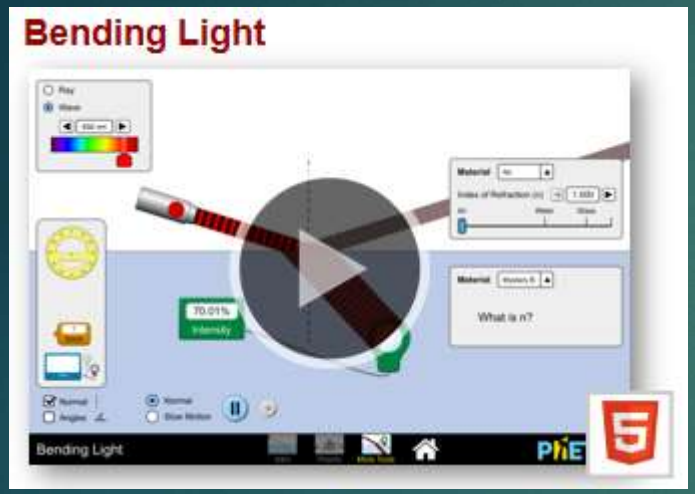
- Example 1: Light travels from air into water. The incident angle was 60°. Calculate the angle of refraction.

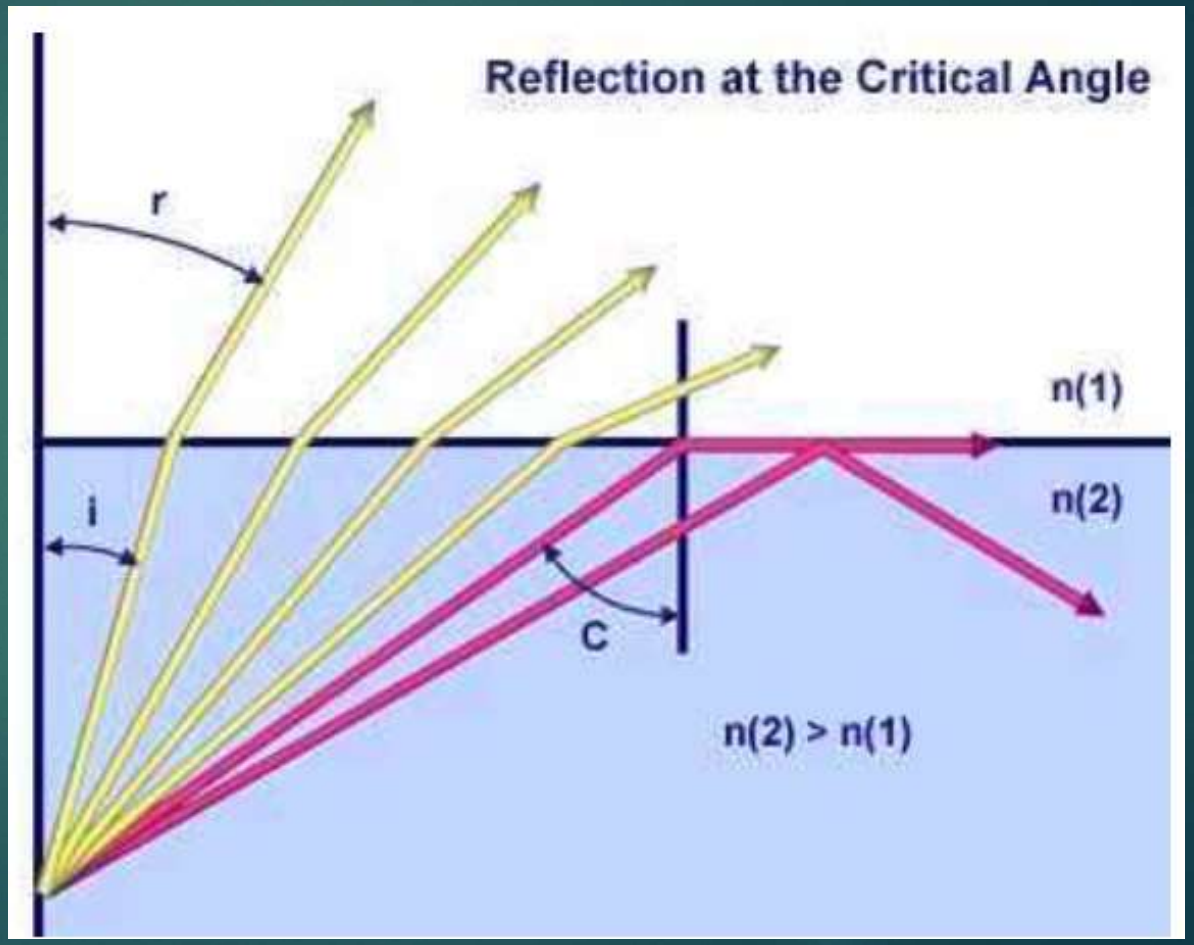
Snell's Law Examples

- Example 2: Light travels from zircon into an unknown material. The angle of incidence was 33° and the angle of refraction was 42°. Calculate the speed of light in the unknown material.

- Example 3: Light is traveling from water into flint glass. Calculate the largest possible angle of refraction.

Total Internal Reflection & Critical Angle





Total Internal Reflection & Critical Angle

- Recall that when entering a new medium, some light is reflected and some is refracted.
- Total internal reflection occurs when light travels into a faster medium and the angle of refraction would calculate to 90° (or greater).
- When the angle of refraction is 90°, the angle of incidence is called the ***critical angle***, θ_c.
- Angles of incidence greater than θ_c result in total internal reflection.
  - Fiber optical cables apply this theory to keep a significant amount of light from exciting the cable.

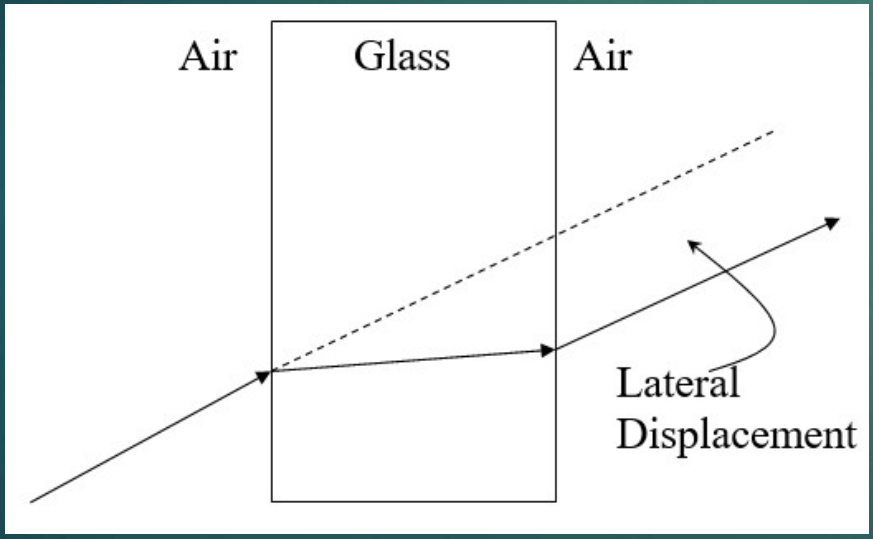
Total Internal Reflection & Critical Angle

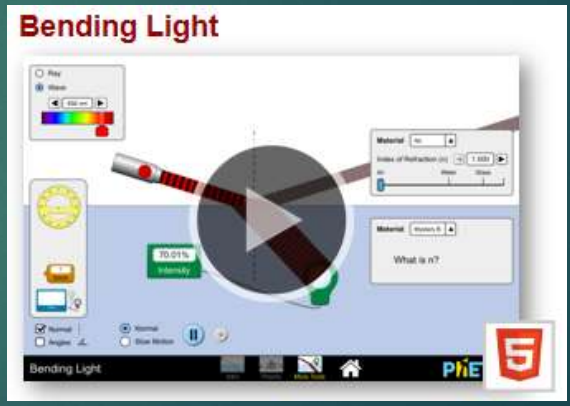
- Example 1: Calculate the critical angle for light traveling from water into air.

- Example 2: Calculate the critical angle for light traveling from diamond into sodium chloride.

Lateral Displacement

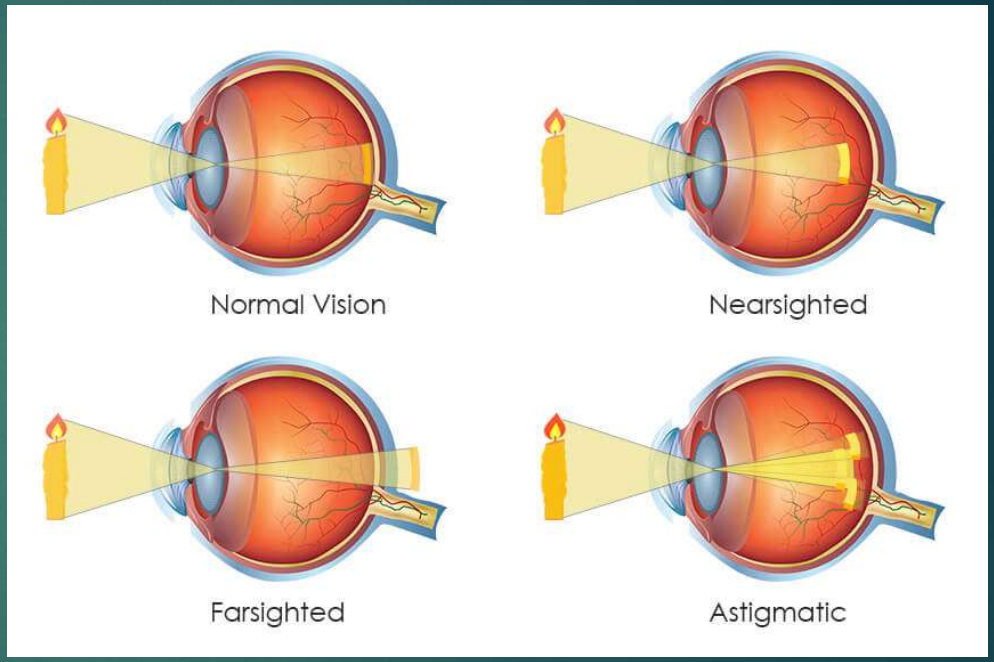
- When light travels from, for example, air into glass, then back into air, it is refracted twice.
- If the two refracting surfaces are parallel, the emergent ray is parallel to the incident ray, but displaced by a certain amount.





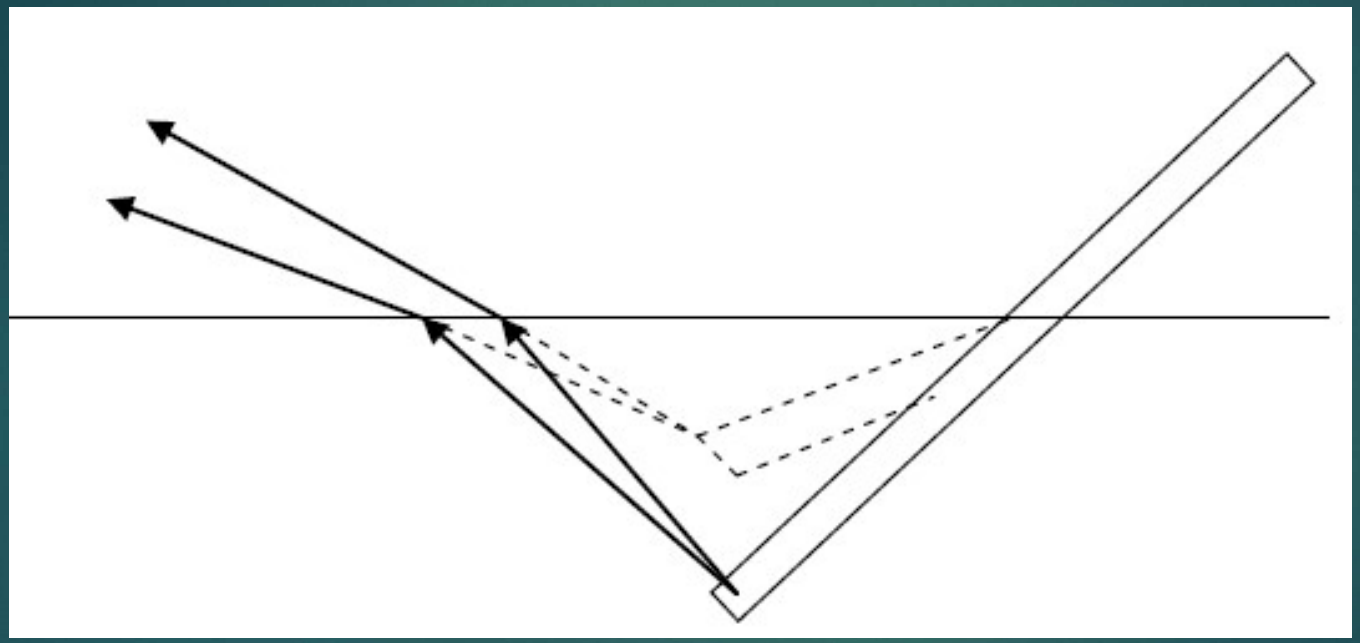
Applications of Refraction

- Eyes
- Lenses (glasses, contact lenses, cameras, telescopes)
- Fiber optic cable
- Rear-view mirror dimming.



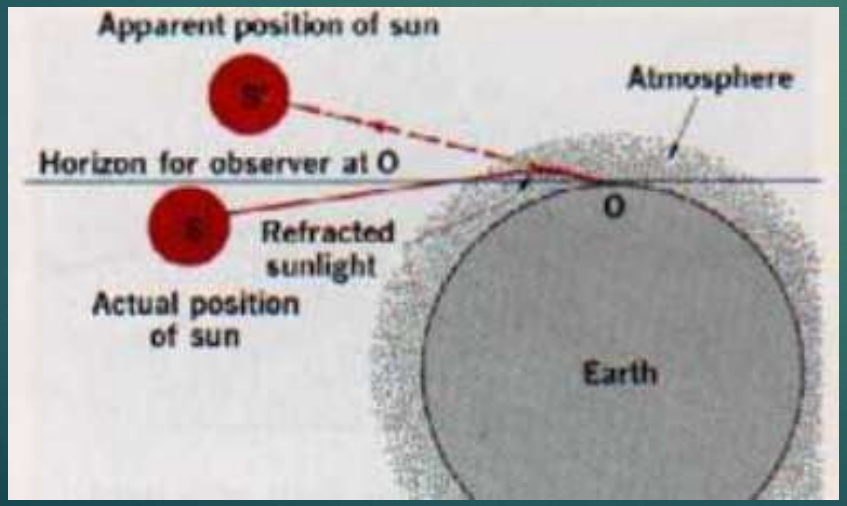
Applications of Refraction

- Distortions as light exits a liquid (the bent spoon).



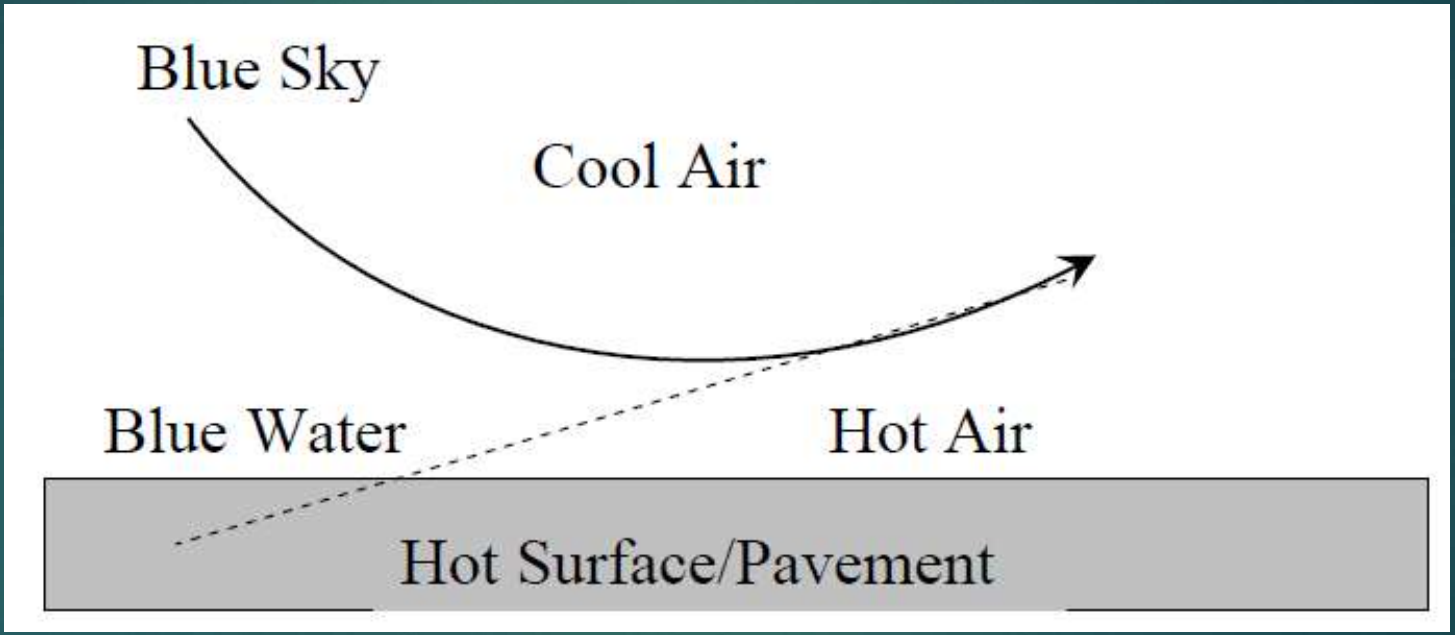
Applications of Refraction

- Distortions as light as it travels through the atmosphere.
  - Sunset/rise: Sun is actually below the horizon, but we can see it.
  - Twinkling stars
  - Waves in the air near heat sources.



Applications of Refraction

- Puddle mirage on the road.



Applications of Refraction

- Red Moon during lunar eclipse
- Other colors have smaller wavelengths and are scattered by the particles in the atmosphere.