

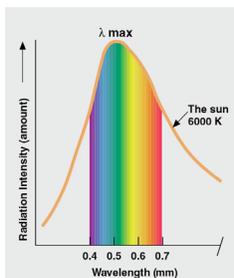
Chapter 4

Light, Color, and Atmospheric Optics

Questions

- Why is the sky blue?
- Why are clouds white?
- Why is the sun orange at sunset and white during the day?
- What causes stars to twinkle?
- What is twilight?
- What causes a mirage?
- What causes a rainbow?

Perception of Color

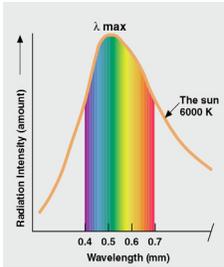


The human eye can perceive color for wavelengths between $0.4\mu\text{m}$ (violet) and $0.7\mu\text{m}$ (red).

We see white light when all visible wavelengths have equal intensity.

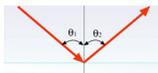
We see red when there is a greater intensity of red light, and we see blue when there is a greater intensity of blue light.

Color of Objects

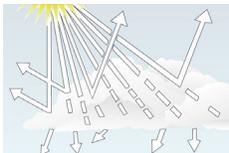


- A red object absorbs all visible light except red light.
- A blue object absorbs all visible light except blue light.
- A black object absorbs all visible light and does not reflect light back.

Reflection and Scattering



- Reflection – light deflected in one direction for a given incident ray.



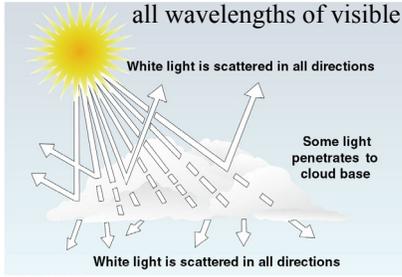
- Scattering – light deflected in all directions.

Why is the sky blue?

- Air molecules (oxygen and nitrogen) selectively scatter the shorter wavelengths of visible light more.
- Thus, scattered waves of violet, blue and green strike the eye from all directions.
- Because our eyes are more sensitive to blue light, we see the sky as blue.

Why are clouds white?

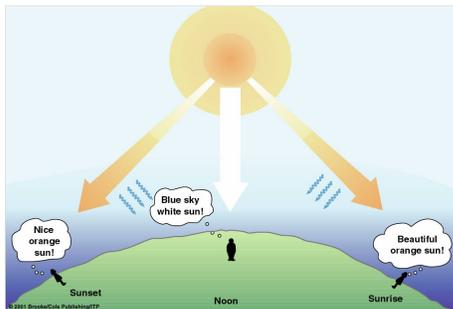
Water droplets in clouds scatter all wavelengths of visible light.



Why is the sun orange at sunset?

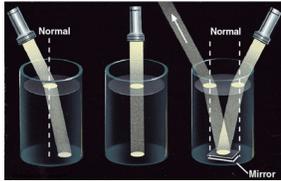
- Near sunrise or sunset the light from the sun must travel through much more of the atmosphere than at any other time of day.
- By the time the light reaches us, the shorter wavelengths (like blue light) have been scattered away.
- This leaves only the longer wavelengths such as red, yellow, and orange.

Summary of Color of Sky & Sun

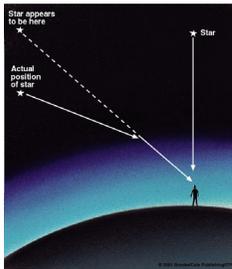


Refraction

- Light that travels from a less-dense to a more-dense medium bends towards the normal.
- Light that travels from a more-dense to a less-dense medium bends away from the normal.

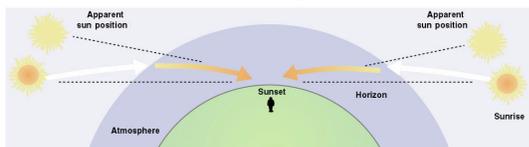


Twinkling Stars



- Because of refraction, star light is bent by the atmosphere.
- Star light passing through regions of differing air density causes the position of the star to appear to change (called twinkle or scintillation).

Twilight



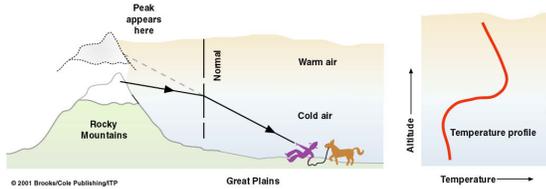
- The atmosphere refracts and scatters light into our eyes even after the sun has set.

Mirages



- Mirages are created by light passing through and being bent by air layers of different density.
- The apparent wet pavement above is caused by blue skylight refracted up into our eyes as it travels through air of different densities.

Another Mirage Example

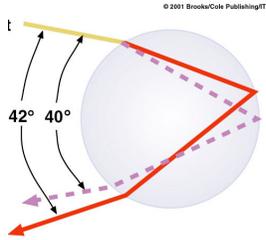


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Total Internal Reflection

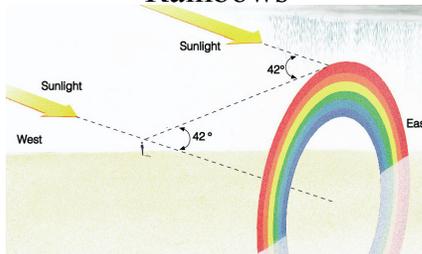
- When light goes from a more dense medium (water) to a less dense medium (air), it is bent away from the normal.
- The most it can be bent is 90° .
- Thus, at some point it is not possible for the light to be bent enough, and all the light is reflected.
- For water, light coming in at an angle greater than 48° to the normal will be totally internally reflected.

Reflection in Rain Drops



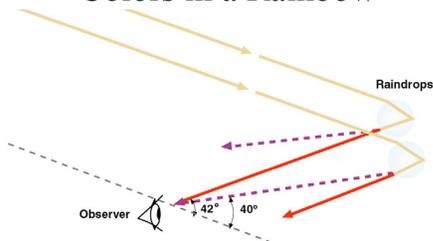
- Light can be totally internally reflected in rain drops.
- The bending of the light (refraction) depends on the wavelength of the light as in a prism.

Rainbows



- Rainbows are caused by refraction and total internal reflection from rain drops.
- Note: the sun must be behind you to see a rainbow.

Colors in a Rainbow



- Red appears at the top of the rainbow even though the red light is bent more.

Summary

- The blue sky, white clouds, and the sun being orange at sunset are all caused by scattering of light.
- Twinkling stars, twilight, mirages, and rainbows are caused by the refraction of light in the atmosphere.
