The Nature and Propagation of Light

DispersionPolarization





Phys P214/3522C10app331, PPg 1



The Visible Spectrum

Remember that white light contains all the colors of the

spectrum



each color in the spectrum has a different wavelength and frequency (recall c = λ f)

Dispersion

- We know the speed of light changes in a medium: v = c / n
- When light travels from one medium to another:
 - **•** wavelength changes too ! (recall that $v = f \lambda$)
 - frequency does not change

$$\boldsymbol{n} = \frac{\boldsymbol{c}}{\boldsymbol{v}} = \frac{\boldsymbol{f} \cdot \boldsymbol{\lambda}_{0}}{\boldsymbol{f} \cdot \boldsymbol{\lambda}} = \frac{\boldsymbol{\lambda}_{0}}{\boldsymbol{\lambda}}$$

- refractive index depends on λ
 (different n for different colors)
 - \rightarrow n decreases as λ increases



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Dispersion

n decreases as λ increases



- For red light (λ = 700 nm) ⇒ n smaller (less bending)
- **i** for blue light ($\lambda = 400$ nm) \Rightarrow n bigger (more bending)
- spreading (dispersion) of colors due to refraction !



How does a rainbow form?

light is refracted by spherical water droplets
 red light is bent at a lesser angle (top of rainbow)
 violet light is bent at a greater angle (bottom of rainbow)



A Diamond is Forever

Total internal reflection

- High n=2.4. So critical angle is about 25 degrees
- Many internal reflections before exiting.

Dispersion

Colors are separated after many travels, before emerging individually and brilliantly.



Polarization

The E field in an EM wave is perpendicular to the direction of travel.

But there are many possible orientations for the E field!

polarized light

unpolarized light



millions of E field oscillates electrons in all directions 3-D view:

In polarized light, all of the electric fields in the wave oscillate in the same direction 3 2435: Chap. 33, Pg 9



Polarizer



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How much light gets through?



Example: two polarizers in combination

If the incident light has intensity I₀, what are the intensities transmittied by the 1st and 2nd polarizers if the angle between the axes of the two filters is 30 degrees?



The intensity after passing the 1st filter is $I_0/2$. After passing the 2nd filter it becomes $I_0/2 \ge \cos^2 30^0 = 3I_0/8$.

Polarization by Reflection



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 θ_{p} is called polarizing angle.

Polarization by Reflection

Polarizing angle (Brewster's Angle): reflected light is totally linear-polarized perpendicular to the incident plane when the incident angle is given by Normal

$$\tan \theta_p = \frac{n_b}{n_a}$$

The refracted light is partially polarized parallel to the incident plane



The reflected light is perpendicular to the refracted light if incident at Brewster's angle.

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Example: Polarization

from air to water

from water to air



Circular Polarization

- Superposition of two linearly-polarized waves at right angles with each other.
 - right circularly-polarized: clockwise
 - Ieft circularly-polarized: counter-clockwise



Why is the sky blue, clouds white, and sunset red?

- Scattering of light: Light can be absorbed by molecules and reemittied in a variety of directions.
- The intensity of the scattered light is proportional to frequency to the 4th power (or inversely proportional to fourth power of the wavelength). This is called Rayleigh scattering).
- The intensity ratio for the two ends of the visible light is (blue/red)⁴ = (700nm/400nm)⁴ = 9.4
 - that's why the sky is blue
- Cloud has high concentration of water molecules. Light of all wavelengths is essentially scattered out of the cloud.

that's why the cloud is white.

 Near sunset, sunlight has to travel long distances to reach you. Most of the blue light is scattered away. White minus blue is yellowish or reddish.

that's why the sunset is red.

ConcepTest 33.5

If unpolarized light is incident from the left, at which of the points will there be some light?

- a) 1
- b) 2
- **c)** 3
- d) none of them
- e) all of them



ConcepTest 33.6

Suppose the axis of the 2nd polarizer is oriented 45^o relative to the 1st polarizer, and the intensity of the incident light is I₀. How much light emerges from the 3rd polarizer? **Polarization**

a) 0 b) $l_0/1.4$ c) $l_0/2$ d) $l_0/4$ e) $l_0/8$

