

10.S: The Nature of Light (Summary)

Key Terms

birefringent	refers to crystals that split an unpolarized beam of light into two beams
Brewster's angle	angle of incidence at which the reflected light is completely polarized
Brewster's law	$\tan \theta_b = \frac{n_2}{n_1}$, where n_1 is the medium in which the incident and reflected light travel and n_2 is the index of refraction of the medium that forms the interface that reflects the light
corner reflector	object consisting of two (or three) mutually perpendicular reflecting surfaces, so that the light that enters is reflected back exactly parallel to the direction from which it came
critical angle	incident angle that produces an angle of refraction of 90°
direction of polarization	direction parallel to the electric field for EM waves
dispersion	spreading of light into its spectrum of wavelengths
geometric optics	part of optics dealing with the ray aspect of light
horizontally polarized	oscillations are in a horizontal plane
Huygens's principle	every point on a wave front is a source of wavelets that spread out in the forward direction at the same speed as the wave itself; the new wave front is a plane tangent to all of the wavelets
index of refraction	for a material, the ratio of the speed of light in a vacuum to that in a material
law of reflection	angle of reflection equals the angle of incidence
law of refraction	when a light ray crosses from one medium to another, it changes direction by an amount that depends on the index of refraction of each medium and the sines of the angle of incidence and angle of refraction
Malus's law	where I_0 is the intensity of the polarized wave before passing through the filter
optically active	substances that rotate the plane of polarization of light passing through them
polarization	attribute that wave oscillations have a definite direction relative to the direction of propagation of the wave
polarized	refers to waves having the electric and magnetic field oscillations in a definite direction
ray	straight line that originates at some point
refraction	changing of a light ray's direction when it passes through variations in matter
total internal reflection	phenomenon at the boundary between two media such that all the light is reflected and no refraction occurs
unpolarized	refers to waves that are randomly polarized
vertically polarized	oscillations are in a vertical plane
wave optics	part of optics dealing with the wave aspect of light

Key Equations

Speed of light	$c = 2.99792458 \times 10^8 \text{ m/s} \approx 3.00 \times 10^8 \text{ m/s}$
Index of refraction	$n = \frac{c}{v}$

Law of reflection	$\theta_r = \theta_i$
Law of refraction (Snell's law)	$n_1 \sin \theta_1 = n_2 \sin \theta_2$
Critical angle	$\theta_c = \sin^{-1} \left(\frac{n_2}{n_1} \right)$ for $n_1 > n_2$
Malus's law	$I = I_0 \cos^2 \theta$
Brewster's law	$\tan \theta_b = \frac{n_2}{n_1}$

Summary

1.1: The Propagation of Light

- The speed of light in a vacuum is $c = 2.99792458 \times 10^8 \text{ m/s} \approx 3.00 \times 10^8 \text{ m/s}$.
- The index of refraction of a material is $n = c/v$, where v is the speed of light in a material and c is the speed of light in a vacuum.
- The ray model of light describes the path of light as straight lines. The part of optics dealing with the ray aspect of light is called geometric optics.
- Light can travel in three ways from a source to another location: (1) directly from the source through empty space; (2) through various media; and (3) after being reflected from a mirror.

1.2: The Law of Reflection

- When a light ray strikes a smooth surface, the angle of reflection equals the angle of incidence.
- A mirror has a smooth surface and reflects light at specific angles.
- Light is diffused when it reflects from a rough surface.

1.3: Refraction

- The change of a light ray's direction when it passes through variations in matter is called refraction.
- The law of refraction, also called Snell's law, relates the indices of refraction for two media at an interface to the change in angle of a light ray passing through that interface.

1.4: Total Internal Reflection

- The incident angle that produces an angle of refraction of 90° is called the critical angle.
- Total internal reflection is a phenomenon that occurs at the boundary between two media, such that if the incident angle in the first medium is greater than the critical angle, then all the light is reflected back into that medium.
- Fiber optics involves the transmission of light down fibers of plastic or glass, applying the principle of total internal reflection.
- Cladding prevents light from being transmitted between fibers in a bundle.
- Diamonds sparkle due to total internal reflection coupled with a large index of refraction.

1.5: Dispersion

- The spreading of white light into its full spectrum of wavelengths is called dispersion.
- Rainbows are produced by a combination of refraction and reflection, and involve the dispersion of sunlight into a continuous distribution of colors.
- Dispersion produces beautiful rainbows but also causes problems in certain optical systems.

1.6: Huygens's Principle

- According to Huygens's principle, every point on a wave front is a source of wavelets that spread out in the forward direction at the same speed as the wave itself. The new wave front is tangent to all of the wavelets.
- A mirror reflects an incoming wave at an angle equal to the incident angle, verifying the law of reflection.
- The law of refraction can be explained by applying Huygens's principle to a wave front passing from one medium to another.
- The bending of a wave around the edges of an opening or an obstacle is called diffraction.

1.7: Polarization

- Polarization is the attribute that wave oscillations have a definite direction relative to the direction of propagation of the wave. The direction of polarization is defined to be the direction parallel to the electric field of the EM wave.
- Unpolarized light is composed of many rays having random polarization directions.

- Unpolarized light can be polarized by passing it through a polarizing filter or other polarizing material. The process of polarizing light decreases its intensity by a factor of 2.
- The intensity, I , of polarized light after passing through a polarizing filter is $I = I_0 \cos^2 \theta$, where I_0 is the incident intensity and θ is the angle between the direction of polarization and the axis of the filter.
- Polarization is also produced by reflection.
- Brewster's law states that reflected light is completely polarized at the angle of reflection θ_b , known as Brewster's angle.
- Polarization can also be produced by scattering.
- Several types of optically active substances rotate the direction of polarization of light passing through them.

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