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Answer Key: Clear Your Cognitive Path: Advanced Optics for University Physicists

Quantify phase shifts and analyze wavefront aberrations as you tackle complex non-paraxial ray tracing and dielectric boundary conditions.

1. A monochromatic beam transitions from a vacuum into a non-magnetic dissipative medium with a complex refractive index $\tilde{n} = n + ik$. Which physical phenomenon is fundamentally described by the imaginary component κ ?

Answer: B) The attenuation of the wave amplitude as it propagates through the medium

In complex notation, the imaginary part of the refractive index (extinction coefficient) accounts for the exponential decay of the wave amplitude, according to Beer-Lambert law principles within the Maxwell equations framework.

2. When considering the Abbe Sine Condition for an optical system to be free of coma, the magnification must be constant for all rays, satisfying the relation: _____. (Assume n and n' are refractive indices of object and image space).

Answer: A) $n \sin(\theta) / n' \sin(\theta') = \beta$

The Abbe Sine Condition maintains that for a system to produce a sharp image of an off-axis point (eliminating coma), the ratio of the sines of the angles of the rays in object and image space must be constant.

3. True or False: In a birefringent uniaxial crystal, the 'extraordinary' ray behaves according to Snell's Law at all angles of incidence relative to the optic axis.

Answer: B) False

The extraordinary ray's refractive index depends on its direction of propagation relative to the optic axis, meaning it generally does not obey Snell's Law unless propagating along specific symmetry axes.

4. Evaluate the transverse Goos-Hänchen shift. This phenomenon occurs during total internal reflection because:

Answer: C) An evanescent wave penetrates the lower-index medium before re-emerging

The Goos-Hänchen shift is a lateral displacement caused by the finite penetration of an evanescent wave into the rarer medium, shifting the reflected beam's position compared to what geometric optics predicts.

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5. In Fourier Optics, a thin lens of focal length 'f' placed a distance 'f' from an object acts as a natural processor that performs a _____ of the input field distribution.

Answer: C) 2D Fourier Transform

A lens in a $2f$ configuration maps the spatial frequencies of the object to spatial coordinates in its back focal plane, effectively computing a Fourier Transform of the complex amplitude.

6. True or False: According to the Fermat Principle of Least Time, light traveling through a medium with a non-uniform refractive index will always take the path of shortest geometrical distance.

Answer: B) False

Fermat's Principle states that light takes the path of stationary optical path length (usually the minimum time), which in a gradient-index medium is a curved path, not a straight geometrical line.

7. Consider a Fabry-Pérot interferometer with a high finesse. What happens to the transmission peaks as the reflectivity of the mirrors approaches unity?

Answer: D) The peaks become significantly narrower, increasing spectral resolution

Finesse is directly proportional to mirror reflectivity. Higher reflectivity increases the number of internal reflections, which sharpens the interference fringes (narrowing the FWHM).

8. The Malus Law describes the intensity of light passing through a polarizer. For a beam with initial intensity I_0 passing through two polarizers with an angle ' α ' between their transmission axes, the output intensity is _____.

Answer: B) $I = I_0 \cos^2(\alpha)$

Malus' Law states that the transmitted intensity varies as the square of the cosine of the angle between the light's polarization direction and the polarizer's axis.

9. An achromatic doublet is designed primarily to correct which of the following third-order aberrations by using two different glass types (e.g., crown and flint)?

Answer: C) Chromatic Aberration

Achromatic doublets use materials with different dispersive powers (Abbe numbers) to bring two distinct wavelengths (typically red and blue) to a common focus, mitigating chromatic aberration.

10. True or False: In a step-index optical fiber, the V-number (normalized frequency) must be less than 2.405 to ensure strictly single-mode propagation.

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Answer: A) True

The V-parameter determines the number of modes. For single-mode operation in a step-index fiber, $V < 2.405$ prevents the first higher-order mode (TE₀₁/TM₀₁/HE₂₁) from reaching cut-off.