Problem statements:

Q.1 A silica optical fiber with a core diameter range and to be considered by ray theory analysis has a core refractive index of 1.498 and a cladding refractive index of 1.465

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Determine a) the critical angle at core-cladding interface
b) Numerical aperture
c) the acceptance angle in air

→ Given data:

$n_1 = 1.49$, $n_2 = 1.465$

$\phi_c = ?$

$NA = ?$

$\theta_c = ?$

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

$NA = n_0 \sin\theta_a = \sqrt{n_1^2 - n_2^2} = n_1\sqrt{2\Delta}$

$\sin\phi_c = \frac{n_2}{n_1}$

$\therefore NA = \sqrt{n_1^2 - n_2^2}$

$= \sqrt{(1.498)^2 - (1.465)^2}$

$= (1.498)^2 - (1.465)^2)^{\frac{1}{2}}$

$\therefore NA = 0.31$

$NA = n_0 \sin\theta_0 = \theta_c = \sin^{-1}\left(\frac{NA}{n_0}\right)$

Q.2 The velocity of light in core of step index fiber is 2.0×10^8 m/s and critical angle at core-cladding interface is 80°. Determine NA and acceptance angle for fiber in air.

→ Given

$V = 2.0 \times 10^8$

$\phi_c = 80°$

$NA = ?$

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$\theta_q = 2$

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

$\sin \phi_c = \frac{n_2}{n_1}$

Velocity of light in vacuum $= 3 \times 10^8$

$\therefore n = \frac{c}{v} = \frac{3 \times 10^8}{2.01 \times 10^8} = 1.49$

$\therefore n_1 = 1.49$

$\sin \phi_c = \frac{n_2}{n_1}$

$n_2 = \sin \phi_c \cdot n_1$

$n_2 = \sin(80) \cdot 1.49$

$n_2 = 1.46$

$NA = (n_1^2 - n_2^2)^{\frac{1}{2}}$

$NA = (1.49^2 - 1.46^2)^{\frac{1}{2}}$

$NA = 0.29$

$\theta_0 = \sin^{-1}(NA)$

$\theta_c = \sin^{-1}(0.29)$

$\theta_c = 16.85$

Q.3 A step index fiber with a large core diameter compared with wavelength of transmitted light has an acceptance angle of 22° and a relative refractive index difference of 3%. Estimate the numerical aperture and the critical angle at core-cladding interface for the fiber.

→ Given

$\theta_c = 22°$

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$n_0 = 1$

$\Delta = 0.03$

$NA = ?$

$\phi C = ?$

$NA = \sin\theta_a$

$NA = \sin(21^\circ)$

$\therefore NA = 0.37$

$NA = n_1 (2\Delta)^{1/2}$

$\therefore n_1 = \frac{NA}{(2\Delta)^{1/2}}$

$n_1 = \frac{0.37}{(2 \times 0.03)^{1/2}}$

$\therefore n_1 = 1.51$

$NA = (n_1^2 - n_2^2)^{1/2}$

$NA^2 = (n_1^2 - n_2^2)$

$n_2^2 = n_1^2 - NA^2$

$n_2^2 = 2.14$

$n_2 = 1.46$

$\phi c = \sin^{-1}\left(\frac{n_2}{n_1}\right)$

$\phi c = \sin^{-1}\left(\frac{1.46}{1.51}\right) = 75.21^\circ$

Q.4 Calculate refractive index of core and cladding if NA = 0.35 and relative refractive index difference is 0.01

→ Given:

$NA = 0.35$

$\Delta = 0.01$

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$n_1 = ?$

$n_2 = ?$

$NA = n_1 (2\Delta)^{\frac{1}{2}}$

$$n_1 = \frac{NA}{(2\Delta)^{1/2}}$$

$n_1 = 2.47$

$NA = (n_1^2 - n_2^2)^{1/2}$

$NA^2 = n_1^2 - n_2^2$

$n_2^2 = n_1^2 - NA^2$

$n_2^2 = n_1^2 - NA^2$

$n_2^2 = (2.47)^2 - (0.35)^2$

$n_2^2 = 5.97$

$n_2 = \sqrt{5.97}$

$n_2 = 2.44$

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