[4] $\Delta = \frac{n_1 - n_2}{n_1} \implies 1 - \frac{n_2}{n_1} = 0.01$

$n_2 = 0.99 n_1 = 1.445$

$\sin\theta_c = \frac{n_2}{n_1} = \frac{1.445}{1.46} \implies \theta_c = 81.89°$

$\sin\theta_{imax} = n_1\sqrt{2\Delta} = 1.445\sqrt{2(0.01)} \implies \theta_{imax} = 11.79°$

$NA = n_a \sin\theta_{imax} = 0.209$

[5] $\Delta = \frac{(NA)^2}{2n_1^2} = \frac{(0.21)^2}{2(1.448)^2} = 0.0105$

$0.0105 = \frac{n_1 - n_2}{n_1} = \frac{1.448 - n_2}{1.448} \implies n_2 = 1.433$

[6] $NA = n_a \sin\theta_{imax} \implies 0.2 = 1.33 \sin\theta_{imax}$

$\theta_{imax} = \sin^{-1}\frac{0.2}{1.33} = 8.65°$

$n_a \sin\theta_{imax} = n_1 \cos\theta_c$

$\frac{n_a \sin\theta_{imax}}{\sin\theta_c} = \frac{n_1}{\tan\theta_c}$

$\frac{n_a \sin\theta_{imax}}{\frac{n_2}{n_1}} = \frac{n_1}{\tan\theta_c} \implies \tan\theta_c = \frac{n_2}{NA}$

$\theta_c = \tan^{-1}\frac{1.59}{0.2} = 82.83°$

$\sin\theta_c = \frac{n_2}{n_1} \implies n_1 = 1.6025$

$NA = \sqrt{{n_1}^2 - {n_2}^2} \approx 0.2$ as given

[7] (HW) Solve it by your self

[8] Condition of single mode

$$V = \frac{2\pi a}{\lambda} NA \leq 2.405$$

$$NA = \sqrt{{n_1}^2 - {n_2}^2} = 0.1316$$

$$\therefore \lambda \geq \frac{2\pi a}{V} NA \geq 1.375\mu m$$

[9] $\Delta = \frac{n_1 - n_2}{n_1} \implies 1 - \frac{n_2}{n_1} = 0.01$

$$n_2 = 0.99 n_1 = 1.445$$

$$NA = n_1\sqrt{2\Delta} = 1.46\sqrt{2(0.01)} = 0.206$$

Condition of single mode

$$V = \frac{2\pi a}{\lambda} NA \leq 2.405$$

$$V_{max} = \frac{2\pi a}{\lambda_{min}} NA = \frac{2\pi a f_{max}}{c} NA = 2.405$$

$$f_{max} = 1.112 \times 10^{14}\text{Hz}$$

[10] $n_1 = 1.5, \alpha = 1.9, \Delta = 1.3\%, 2a = 40\mu\text{m}, \lambda = 1.55\mu\text{m}$

$$V = \frac{2\pi a}{\lambda} NA = \frac{2\pi a}{\lambda}\left(n_1\sqrt{2\Delta}\right)$$

$$V = \frac{2\pi(20 \times 10^{-6})}{1.55 \times 10^{-6}} \times 1.5 \times \sqrt{2(0.013)} = 19.6$$

$$M_{GI} = M_{SI}\left(\frac{\alpha}{\alpha + 2}\right)$$

$$M_{GI} = \frac{V^2}{4} = 96$$

Condition of single mode

$$V_c = 2.405\left(1+\frac{2}{\alpha}\right)^{\frac{1}{2}}$$

$$V_c = 3.4456$$

[11] $V = \frac{2\pi a}{\lambda} NA = \frac{2\pi a}{\lambda}\left(n_1\sqrt{2\Delta}\right) = 75.8$

$$M = \frac{V^2}{2} = 2873$$

$$a = \frac{\lambda V}{2\pi(n_1\sqrt{2\Delta})} = \frac{2.405 \times 0.85 \times 10^{-6}}{2\pi(1.48\sqrt{2(0.015)})} = 1.27\mu m$$

After reduction of Δ 10 times

$$a = \frac{\lambda V}{2\pi(n_1\sqrt{2\Delta})} = \frac{2.405 \times 0.85 \times 10^{-6}}{2\pi(1.48\sqrt{2(0.0015)})} = 4\mu m$$

[12] (HW) Solve it by your self.

Good Luck

Dr. Sherif Hekal