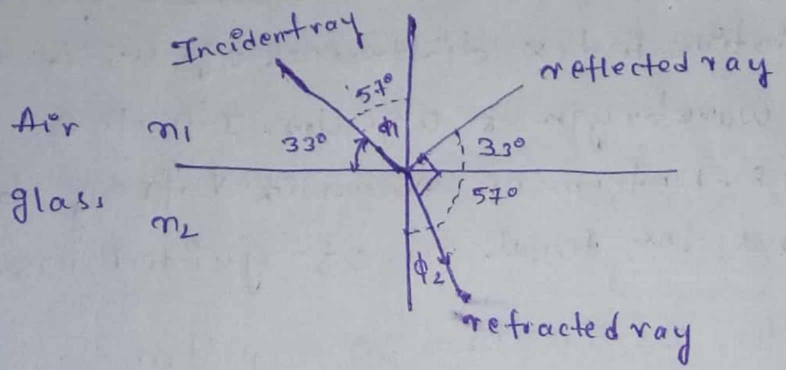
④ Light travelling in air strikes a glass plate at an angle $\theta_1 = 33^\circ$, where θ_1 is measured between the incoming ray and glass surface. If the refracted and reflected beams make an angle of 90° with each other, what is the R.I. of glass? what is the critical angle?



<u>Snell's Law</u>

$$n_1 \sin\phi_1 = n_2 \sin\phi_2$$

$$1 \sin 57^\circ = n_2 \sin 33^\circ$$

$$n_2 = \frac{\sin 57^\circ \; 0.838}{\sin 33^\circ \; 0.544}$$

$$\boxed{n_2 = 1.54}$$

<u>Critical angle</u>

$$\sin\phi_c = \frac{\text{lower index}}{\text{higher index}}$$

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

$$= \frac{1}{1.54}$$

$$\phi = \sin^{-1}(0.649)$$

$$\boxed{\phi = 40.46^\circ}$$

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⑤ A Graded Index fiber has a core with parabolic r.I profile has a diameter of $50\mu m$. The fiber has a numerical aperature of 0.2. Estimate the total number of guided modes propogating in the fiber when it is ~~pr~~operating at wavelength of $1\mu m$?

Sol^n given,

Core diameter $= 50\mu m$ $\quad \therefore a = \frac{50}{2}\mu = 25\mu m$.

$NA = 0.2$

$\lambda = 1\mu m$

parabolic profile, $\alpha = 2$

$M = \frac{V^2}{4}$

$= \frac{(31.4)^2}{4}$

$\boxed{M = 246.49}$

$\therefore V = \frac{2\pi a}{\lambda}(NA)$

$= \frac{2\pi \times 25 \times \cancel{10^{-6}}}{1 \times \cancel{10^{-6}}}(0.2)$

$V = 31.4$

---

(4) Multimode step index fiber with a core diameter of 80μm and relative index difference of 1.5% is operating at a wavelength of 0.85μm. If the core R.I is 1.48. Determine normalized freq for the fiber (v) and the total no. of guided modes

Sol^n Core diameter, $a = 80\mu m = \frac{80}{2} = 40\mu m.$

$\Delta = 1.5\% = \frac{1.5}{100} = 0.015$

$\lambda = 0.85\mu m$

$n_1 = 1.48,$

i) $V = ?$

ii) $M = ?$

i) $V = \frac{2\pi a}{\lambda}(NA)$

$= \frac{2 \times 3.14 \times 40 \times \cancel{10^{-6}}}{0.85 \times \cancel{10^{-6}}} \times n_1\sqrt{2\Delta}$

$= 295.52 \times 1.48\sqrt{2 \times 0.015}$

$\boxed{V = 75.75} \simeq 75.8$

ii) $M = \frac{V^2}{2}$

$= \frac{(75.8)^2}{2}$

$\boxed{M = 2873 \text{ mode}}$

if $V \simeq 76$

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

$= \frac{76^2}{2}$

$\boxed{M = 2888 \text{ modes}}$

③ A Silica optical fiber with a core diameter Large enough to be considered by ray theory analysis has a core refractive index of 1.50 and cladding R.I = 1.47, Determine

i) Critical angle at core cladding interface

ii) Numerical aperature

iii) Acceptance angle in air for the fiber

Solu

$n_1 = 1.5$

$n_2 = 1.47$

$\phi_c = ?$

$NA = ?$

$\theta_a = ?$

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

$= \sin^{-1}\left(\frac{1.47}{1.5}\right)$

$\boxed{\phi_c = 78.5^\circ}$

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

$= \sqrt{1.5^2 - 1.47^2}$

$\boxed{NA = 0.3}$

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

$= \sin^{-1}(0.3)$

$\boxed{\theta_a = 17.45^\circ}$

---

⑥ A multimode Step index fiber has V number of 75 NA = 0.3, R.I = 1.458 and operates at 820nm. Find the core Radius, Refractive index of cladding; fractional change in R.I and no. of modes gets propogated

$V = 75$ $\quad \lambda = 820nm.$

$NA = 0.3$

$n_1 = 1.458$

$a = ?$

$n_2 = ?$

$\Delta = ?$

R.I of cladding,

From, $NA = \sqrt{n_1^2 - n_2^2}$ $NA = (n_1^2 - n_2^2)^{1/2}$

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

$= (1.458)^2 - (0.3)^2$

$n_2^2 = 2.03$

$\boxed{n_2 = 1.42}$

fractional change,

$\Delta = \frac{n_1 - n_2}{n_1}$

$= \frac{1.458 - 1.42}{1.458}$

$= 0.0219$

$\boxed{\Delta = 21.9\%}$

Core of Radius

From $V = \frac{2\pi a}{\lambda}(NA)$

$a = \frac{V\lambda}{2\pi(NA)}$

$= \frac{75 \times 820 \times 10^{-9}}{2 \times 3.14 \times 0.3}$

$a = 32.64 \times 10^{-6} m$

$\boxed{a = 32.64 \mu m}$

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

$= \frac{(75)^2}{2}$

$\boxed{M = 2812.5}$

1) A Step-index multimode fiber with a numerical aperature of 0.20 supports approximetly 1000 modes at an 850nm wavelength

i) what is the diameter of its core

ii) How many modes does the fiber support at 1320nm? 1920nm? 1550nm?

Sol:

$NA = 0.2$

$M = 1000 = \frac{V^2}{2} = 1000$

$\lambda = 850nm$ $\boxed{V = 44.72}$

$d = ?$

$M(1320nm) = ?$

i) $d = a \times 2$

$V = \frac{2\pi a}{\lambda}(NA)$

$a = \frac{V\lambda}{2\pi(NA)}$

$= \frac{44.72 \times 850 \times 10^{-9}}{2 \times 3.14 \times 0.2}$

$\boxed{a = 30.24 \mu m}$

$\therefore d = 30.24 \mu \times 2$

$\boxed{d = 60.48 \mu m}$

ii) $M = \frac{V^2}{2}$

$\Rightarrow V = \frac{2\pi a}{\lambda}(NA)$

$= \frac{2 \times 3.14 \times 30.24 \times 10^{-6}}{1320 \times 10^{-9}} \times 0.2$

$\boxed{V = 28.78}$

$\therefore M = \frac{28.78^2}{2}$

$\boxed{M = 414.14}$

1920nm

$$V = \frac{2\pi a}{\lambda}(NA)$$

$$= \frac{2 \times 3.14 \times 30.24 \times 10^{-6}}{1920 \times 10^{-9}} \times 0.2$$

$$V = 19.78$$

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

$$= \frac{19.78^2}{2}$$

$$\boxed{M = 195.62}$$

1550nm

$$V = \frac{2\pi a}{\lambda}(NA)$$

$$= \frac{2 \times 3.14 \times 30.24 \times 10^{-6}}{1550 \times 10^{-9}} \times 0.2$$

$$= 24.50$$

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

$$= \frac{24.50^2}{2}$$

$$\boxed{M = 300.125}$$

8) Consider a 30km long optical fiber that has an attenuation of 0.8dB/km at 1300nm. calculate the optical o/p power point if 200μW of optical power is launched into the fiber!

$Z = 30km$

$\alpha = 0.8 dB/km$

$P(0) = 200 \mu w$

$P(Z) = ?$

$$\alpha = 10 \times \frac{1}{Z} \log \left[\frac{P(0)}{P(Z)}\right]$$

$$0.8 = 10 \times \frac{1}{30} \log \left[\frac{200 \mu w}{P(z)}\right]$$

$$24 = 10 \log \left[\frac{200 \mu w}{P(Z)}\right]$$

$$\frac{200 \mu w}{P(Z)} = 10^{2.4}$$

$$P(Z) = \frac{200 \mu}{10^{2.4}} = 0.7962 \mu w$$

10) A continous 12 km long optical-fiber link has a loss of 1.5 dB/km. What is the minimum optical power level that must be launched into the fiber to maintain an optical power level of 0.3 μW at the receiving end. What is the required input power if the fiber has a loss of 2.5 dB/km

$Z = 12 km.$

$\alpha = 1.5 dB/km.$

i) $P(0) = 0.3 \mu W$

$P(z) = ?$

ii) $\alpha = 2.5 dB/km$

$P(0) = ?$

i) $\alpha = 10 \times \frac{1}{z} \log\left[\frac{P(0)}{P(z)}\right]$

$1.5 = 10 \times \frac{1}{12} \log\left[\frac{0.3\mu}{P(z)}\right]$

$1.8 = \log\left[\frac{0.3\mu}{P(z)}\right]$

$\frac{0.3\mu}{P(z)} = 10^{1.8}$

$P(z) = \frac{0.3\mu}{10^{1.8}}$

$\boxed{P(z) = 4.75 \times 10^{-9} W}$

ii) $\alpha = 2.5 dB/km$

$\alpha = 10 \times \frac{1}{z} \log\left[\frac{P(0)}{P(z)}\right]$

$2.5 = 10 \times \frac{1}{12} \log\left[\frac{P(0)}{4.75 \times 10^{-9}}\right]$

$$\frac{P(0)}{4.75\times10^{-9}} = 10^3$$

$$\boxed{P(0) = 4.75\,\mu W}$$

(09) The input power to an optical fiber is 2mW while the power measured at the o/p end is 2μW. If the fiber attenuation is 0.5 dB/km. Calculate the Length of the fiber.

$P(0) = 2mW = 2\times10^{-3}$ W

$P(z) = 2\mu W = 2\times10^{-6}$ W

$\alpha = 0.5$ dB/km.

$z = ?$

$$\alpha = 10\times\frac{1}{z}\log\left[\frac{P(0)}{P(z)}\right]$$

$$0.5 = 10\times\frac{1}{z}\log\left[\frac{\cancel{2}\times10^{-3}}{\cancel{2}\times10^{-6}}\right]$$

$$0.5 = 10\times\frac{1}{z}\times3$$

$$\frac{0.5}{30} = \frac{1}{z}$$

$$z = \frac{30}{0.5}$$

$$\boxed{z = 60\,km}$$

① Following are the parameters of point to point optical link

Optical power launched : 3 dBm

Sensitivity of photo-detector : -32 dBm

Source/detector connector loss : 1 dB

length of optical cable : 60 km

Cable attenuation : 0.3 dB/km

Jumper cable loss : 3 dB

Connector loss at each fiber : 1 dB (Joint at two at each transmitter & receiver end because of the Jumper cables?

Compute the power margin of the link?

Parameter	o/p Sensitivity	power Margin (dB)
Laser o/p	3 dBm	
APD Sensitivity	-32 dBm	
Loss [3-(-32)]		35
Source connector loss	1 dB	34
Jumper connector loss (T)	(3+1) dB	30
Cable attenuation	18 dB	12
Jumper connector loss (R)	(3+1) dB	8
RXR connector loss	1 dB	7 power margin