

First Exam	Department of Telecommunications Engineering	Dr. Mohammad Banat
460 هـت – Fall 2011	<u>Optical Fiber Communications</u>	Sun. 30 Oct. 2011 @ 17:00-18:00

- 1) The electric field of the TE<sub>0</sub> mode in a symmetric rectangular dielectric waveguide is given by  $E_{y,1}(x) = A \cos(hx)$ , where  $A$  is a constant and  $h = 1.25 \times 10^5$ . Assume the inner region of the waveguide thickness is  $16 \mu\text{m}$ . Assume the refractive indices of the inner and outer regions are given, respectively, by:  $n_1 = 1.52$  and  $n_2 = 1.5$ .

**1.a.** Sketch the electric field of the TE<sub>0</sub> mode as function of  $x$ . ----- (15)

Cosine function that ends at  $A \cos(1) = 0.54A$  at both sides.

**1.b.** Determine the normalized frequency. ----- (10)

$$pa = \tan(1) = 1.5574 \quad V = \sqrt{1 + (1.5574)^2} = 1.85$$

**1.c.** Determine the wavelength in micro-meters. ----- (10)

$$\lambda = \frac{2\pi a}{V} \sqrt{n_1^2 - n_2^2} = 6.678 \mu\text{m}$$

**1.d.** What other TE modes are present in this waveguide? Explain your answer. --- (15)

TE<sub>1</sub>

- 2) Consider an optical fiber with the following refractive index profile:

$$n(r) = \begin{cases} 1.5, & 0 \leq r < 10 \mu\text{m} \\ 1.45, & 10 \mu\text{m} \leq r < 20 \mu\text{m} \\ 1.40, & 20 \mu\text{m} \leq r \leq 100 \mu\text{m} \end{cases}$$

**2.a.** Determine the acceptance angle. ----- (20)

$1.45 \sin(\varphi_c) = 1.4$ $\varphi_c = 74.91^\circ$	$1.5 \sin(\varphi_1) \geq 1.45 \sin(\varphi_c) = 1.4$ $\varphi_1 \geq 68.96^\circ$	$\sin(\theta_a) \leq 1.5 \cos(\varphi_1) = 0.5385$ $\theta_a \leq 32.58^\circ$
---	---	---

**2.b.** Determine the ratio of the longest ray path length to the shortest ray path length for light rays propagating in this fiber. ----- (15)

$$\frac{1.5L_1 + 1.45L_2}{1.4(L_1 + L_2)} = \frac{1.5L_1 + 1.45L_1 \tan \varphi_c / \tan \varphi_1}{1.4L_1 + 1.4L_1 \tan \varphi_c / \tan \varphi_1} = 1.05$$

**2.c.** Determine the propagation delay difference if the transmission distance along the fiber is 1 km. ----- (15)

$$L_1 = \frac{1000}{2.427} = 412 \text{ m}$$

$$\Delta\tau = \frac{412 * 1.5}{c \sin \varphi_1} + \frac{588 * 1.45}{c \sin \varphi_c} - \frac{1000 * 1.5}{c}$$

$$= 0.15 \mu\text{s}$$