Test 2

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Optoelectronics
Prof. Woo-Young Choi
Dept. of Electrical and Electronic Engineering
Yonsei University

Prob. 1(20)

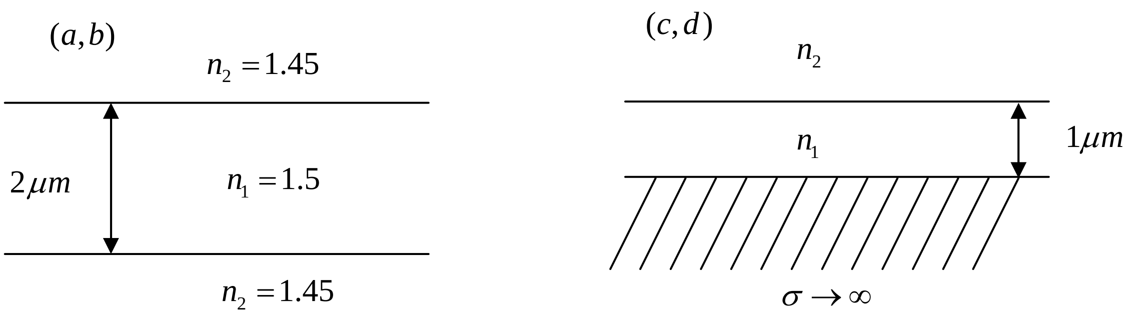
TE-polarized light having λ=1.0μm is guided in a symmetric three-layer dielectric waveguide shown below left.

(a)(5) Determine how many guided modes are supported in this waveguide.

(b)(5) Sketch the guided wave intensity for each mode.

(c)(5) Now the half of the waveguide is replaced with a perfectly-conducting metal as shown below right. Which modes among those determined in (a) can survive?

(d)(5) We would like to increase the number of guided modes by one by making the core height larger than 1.0 μm in the waveguide described in (c). How large should the core height be for the waveguide shown in below right?



Prob. 2 (15)

Determine whether each of following statements is True or False. Briefly explain why. If your answer is False, you may give a counter example as an explanation. Without a clear and correct explanation, you will receive no credit even if your T/F answer is correct.

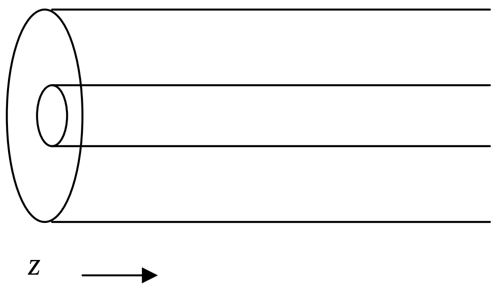
(a)(5) For a guided mode in a three-layer dielectric waveguide, its confinement factor always decreases as the wavelength of the incident lightwave increases. Assume the refractive index is independent of wavelength.

(b)(5) The loss in the fiber is lowest at 1.55μm because both the Rayleigh scattering and lattice absorption are smallest at this wavelength in silica.

(c)(5) In a standard optical fiber having D = 16 ps/nm-km at λ=1.5μm, light with larger wavelength travels faster than that with smaller wavelength.

Prob. 3 (10)

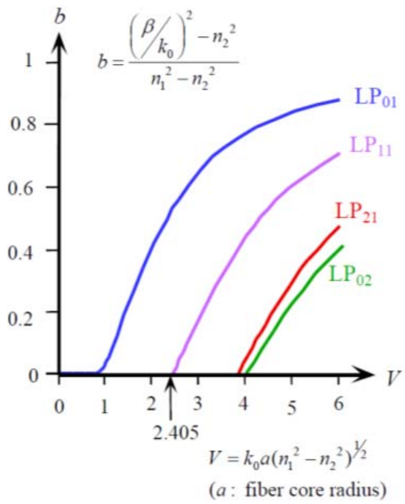
A fiber has its core refractive index given as $n_1(z) = n_0 + \Delta n \sin[(2\pi/d)\, z)$ as shown below. Assume λ=1.5μm and the cladding layer is infinitely thick.



$$n_2 = 1.497$$

$$n_1 = 1.5 + \Delta n \cdot \sin(\frac{2\pi}{d} Z),\ \text{core radius: } 5\mu\text{m}$$

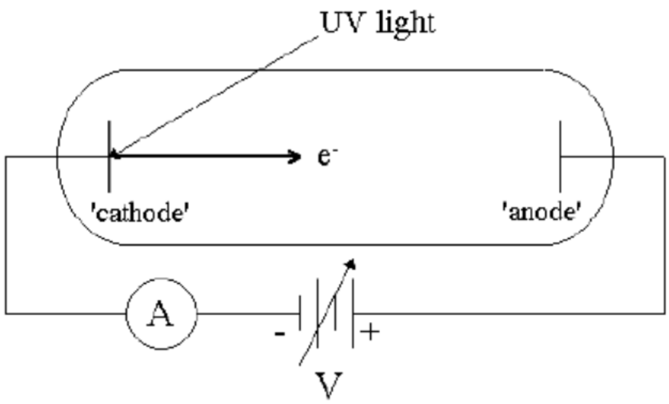
(a)(5) Using the fiber b-V diagram given below, determine the approximate value of the effective index for the fundamental guided mode. Assume Δn=0.



(b)(5) Now assume Δn is very small so that it does not affect the answer determined in (a). Determine the numerical value for the smallest d for which the λ=1.5μm light travelling inside the fiber gets reflected.

<u>Prob. 4(15)</u>

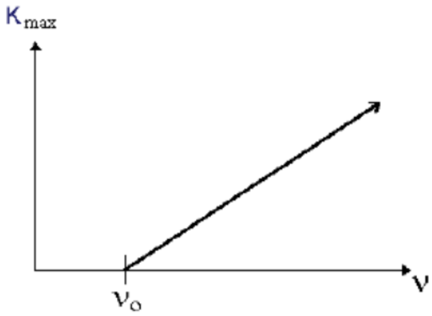
Consider an experiment set-up for the photoelectron effects shown below.



(a)(5) Plot I vs V for two different intensity levels of UV light. I is defined as the current flowing from anode to cathode and V as the potential difference between the two.

(b)(5) Explain how one can measure the maximum kinetic energy, K_{max}, of photoelectrons produced by the UV light.

(c)(5) K_{max} shows the following dependence on the incident light frequency as shown below. Explain why the wave nature of light cannot account for this dependence.



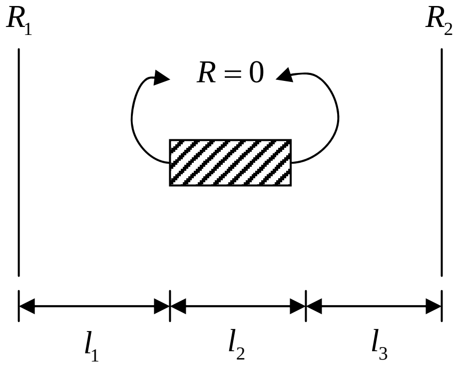
Prob. 5 (20)

Consider a laser made up of a semiconductor gain material and two external mirrors in vacuum as shown below. Both mirrors have the field reflectivity of 0.3. The end facets of the gain material have anti-reflection coatings so that there is no reflection at the end facets. The reflective index of the gain material is 3 and there is no internal loss. Use Γ=1. $l_1=l_2=l_3=10\mu m$.

(a)(5) What is the threshold gain in cm^{-1} for this laser?

(b)(5) Determine the requirement for any lasing wavelength must satisfy.

(c)(5) What is the wavelength separation between adjacent lasing modes around $\lambda=1.0\mu m$?



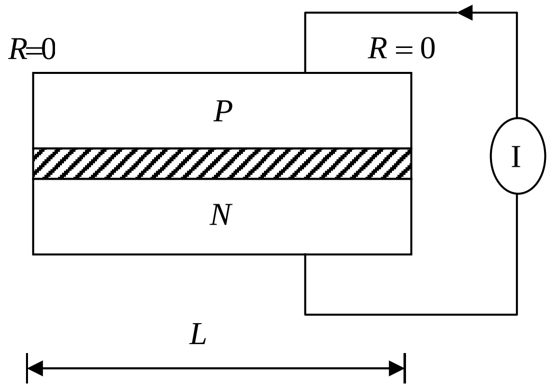
$$l_1 = l_2 = l_3 = 10\mu m$$
$$R_1 = R_2 = 0.3$$

The gain of the material is a function of wavelength and the injected carrier density and is given as $g(\lambda,n) = a\ (n-n_0) - b\ (\lambda-\lambda_0)^2$, where $a = 8\text{x}10^{-16}\ cm^2$, $n_0 = 1\text{x}10^{18}/cm^3$, $b=4800/cm\text{-}\mu m^2$, and $\lambda_0=1.0\mu m$.

(d)(5) At what wavelength the lasing will be observed first and what is the required threshold carrier density?

Prob. 6 (20)

A semiconductor optical amplifier is realized by injecting electron/hole pairs into the active region in a double heterojunction PIN structure shown below. The two facets are coated such that their reflectivities are zero. Input light goes into the amplifier from the left facet and the amplified light comes out from the right facet. The PIN structure has the confinement factor of Γ.



(a)(5) Explain the benefits of using the double heterojunction for this optical amplifier.

(b)(5) Assume the injected electron/hole pairs provide the uniform gain of g cm^{-1} within the active region. What is the expression for the amplifier gain defined as P_{out}/P_{in}?

(c)(5) The same device shown above can be used as a photodetector with the reverse biased PIN junction. Assume 0.5mW of output light is produced with 1mW of input light at 1.5μm, and all the absorbed photons are converted into the photocurrent. What is the responsivity of this photodector?

(d)(5) Propose a way with which the responsivity of the above photodetector can be enhanced.