EE 232 **Midterm Examination-1** Fall 2005

10/10/2005 **EE 232 – Lightwave Devices** Prof. Ming Wu

- If you need additional conditions to solve a problem, please write down your assumptions.

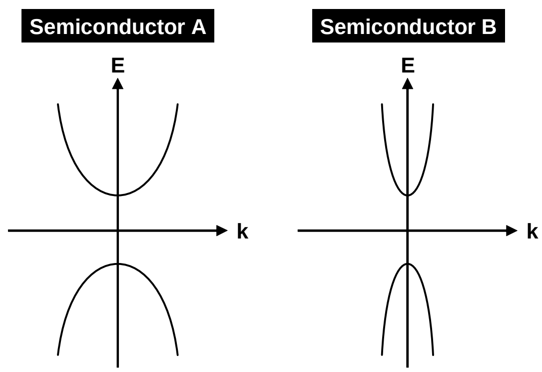
Global Parameters:

Unless stated otherwise in the problem, use the following values for all problems:

Optical matrix element**:**	$M_b^2 = (m_0/6)E_p$, and $E_p = 20\,\text{eV}$
Bandgap energy:	E_g = 1 eV
Relative dielectric constant:	$\varepsilon_r = 12.25$
Refractive index:	$n_r = 3.5$

20 pts.

1. Consider two semiconductors with the following energy band diagrams:



$\boldsymbol{m_C^* = m_V^*} = 0.2\boldsymbol{m}_0$ $\boldsymbol{m_C^* = m_V^*} = 0.1\boldsymbol{m}_0$

Both semiconductors have the same bandgap energy (1 eV) and the same optical matrix elements.

a) Which semiconductor has larger absorption coefficient for a photon energy of 1.1 eV? Explain your answer.

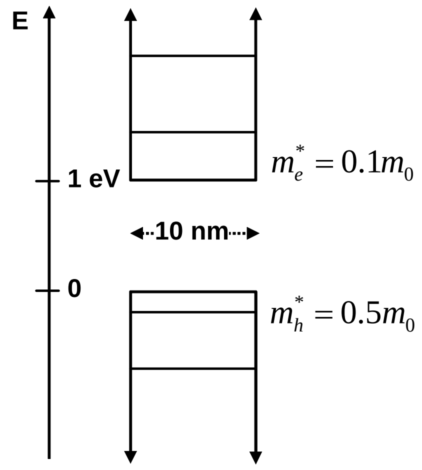
b) If both semiconductors are forward biased such that the electron and hole concentrations are $N = P = 5\times10^{18}\,\text{cm}^{-3}$, which semiconductor has a wider gain bandwidth? Explain your answer.

c) In Part b), which semiconductor has higher peak gain at T = 0 K? Explain your answer.

d) Compare the bias voltages required to achieve the condition in Part b), which semiconductor requires larger forward bias? Explain your answer.

30 pts.

2. Consider the following semiconductor quantum well with infinite well approximation:



a) Find the energies of the first 3 electron subbands and the first 3 hole subbands. For reference, the energy is set to zero at the top of the valance band, i.e., $E_V = 0$.

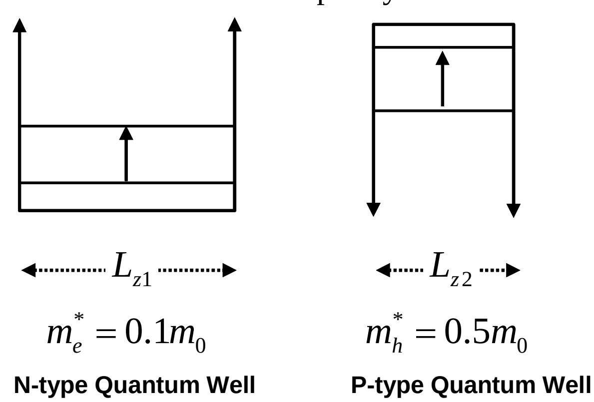
b) If the carrier concentrations are $N = P = 8\text{x}10^{18}$ cm^{-3}, how many electron subbands are occupied? How many hole subbands are occupied?

c) Calculate the electron and hole quasi-Fermi levels.

d) Calculate and plot the interband (conduction-to-valance) gain spectrum of the quantum well with the condition in b). Label both axes quantitatively. Calculate the peak optical gain. (Assume T = 0 K for this part).

30 pts.

3. Consider an N-type and a P-type quantum well inter-subband photodetector shown below. Assume infinite well width for simplicity.



a) If the N-type quantum well width is L_{z1} = 20 nm, what is the peak wavelength of the peak optical absorption?

b) For the P-type quantum well to achieve the same absorption wavelength, what should be its well width?

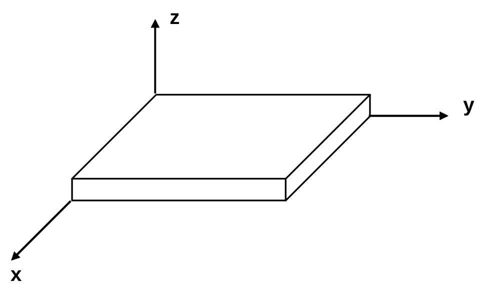
c) Use Lorentzian lineshape with a FWHM of 10 meV for this problem. Find the absorption coefficient of the N-type quantum well (in cm^{-1}) for a doping concentration of 10^{17} cm^{-3}.

d) Continued from Part c), what is the maximum absorption coefficient you can achieve using the N-type quantum well?

e) Which quantum well (N-type or P-type) has larger absorption coefficient, assume the doping concentration in each quantum well is optimized for maximum absorption. Use the well width in b) for the P-type quantum well.

20 pts.

4. Consider the heavy hole-to-electron transition in a semiconductor quantum well shown below. The bandgap energy of the well is 1 eV. Use the global parameters for the effective masses. The width of the quantum well is 10 nm. For simplicity, assume it is an infinite potential well.



a) Find the ratio of the absorption coefficients for TE and TM waves with a photon energy of 1 eV.

b) Repeat Part a) for a photon energy of 1.2 eV.

c) Does the polarization ratio as defined in Part a) depend on the width of the quantum well?