EE 232 | **<u>Midterm Examination-1</u>** | Fall 2009
10/8/2009 | **EE 232 – Lightwave Devices** | Prof. Ming Wu

- If you need additional conditions to solve a problem, please write down your assumptions.
- Answer in the space below the problem. If you need additional space, you can use the overflow pages in the back. Please indicate which page the answer continues in the lower-right corner.
- Please put a square box around your final answers for each problem.

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 $E_p = 24\,\text{eV}$
Bandgap energy:	E_g = 1 eV
Relative dielectric constant:	$\varepsilon_r = 10$
Refractive index:	$n_r = 3.1$

Commonly used constants:

$\hbar = 1.054\times10^{-34}$ J·s	$q = 1.6\times10^{-19}$ C	$m_0 = 9.11\times10^{-31}$ kg
$k_B T = 0.026$ eV at 300K	$k_B = 1.38\times10^{-23}$ J/K	$\varepsilon_0 = 8.854\times10^{-12}$ F/m

Your Name	
Student ID #	
Signature	

Problem	Points	Points Earned
1)	30	
2)*	40	
3)	30	
Total	100	

1. Consider a quantum well with a direct-bandgap semiconductor whose electron and hole effective masses are both equal to $0.5\,m_0$. The interband transition energy from m=1 to n=1 is 1eV. The well width is 10 nm.

   a) What is the maximum optical gain of the semiconductor when the separation of the quasi-Fermi levels is 52 meV above the transition energy? Assume T = 0 K.

   b) What is the spectral width of the optical gain?

   c) What are the electron and hole concentrations for the condition in (a)?

   d) What is the maximum optical gain for the condition in (a) but at room temperature (T = 300 K)?
   (Hint: You can use linear approximation for Fermi inversion factor around $\hbar\omega = \Delta F$)

   e) What is the wavelength of the peak gain in (d)?

   f) What are the electron and hole concentrations for the condition in (d)?

Answer for Problem ___

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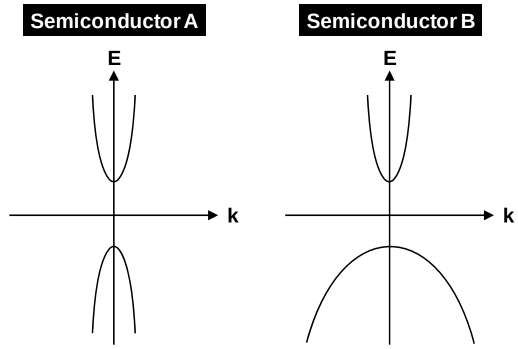
2. Consider two semiconductors with the following energy band diagrams:



$m_e^* = m_h^* = 0.1m_0$

$m_e^* = 0.1m_0$
$m_h^* = 1.0m_0$

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

a) Find the *ratio* of their peak optical gains at T = 0 K when both semiconductors are biased to have the same separation of quasi-Fermi levels (and $\Delta F > E_g$)?

b) How does the *ratio* in (a) change at T = 300K?

c) What is the *ratio* of the electron concentrations for the condition in (a)?

d) Which semiconductor has lower carrier concentration at Bernard-Duraffourg condition (also called transparency condition)? Explain your choice.
(Hint: Use Boltzmann approximation if the quasi-Fermi level is right on band edge).

Answer for Problem ___

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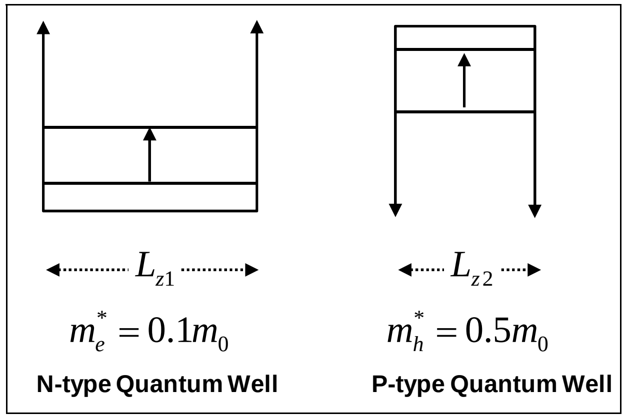
3. Intersubband quantum well infrared photodetector (QWIP) can be made by either N-doped or P-doped quantum wells, as shown on the right. The effective masses of the quantum well materials are shown in the figure.



a) What are the widths of the quantum wells required to achieve a peak detection wavelength of 5μm?

b) Find the *ratio* of the *maximum* absorption coefficients for these two QWIPs.

c) Find the *ratio* of the *minimum* doping concentrations required to achieve maximum absorption coefficients in (b), i.e., N-doping concentration in Semiconductor A / P-doping concentration in Semiconductor B.

Answer for Problem ___

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