Department of Electrical and Computer Engineering
UNIVERSITY OF BRITISH COLUMBIA
EECE 480 SEMICONDUCTOR DEVICES: PHYSICS, DESIGN and ANALYSIS

MID-TERM EXAM, October 23, 2008

Time: 1.25 hours
The exam grade will be out of 20 marks, so it is possible to obtain a score of greater than 100%.
Notes, books and simple calculators are allowed.
Data-storage- or telecommunication-devices are not allowed.
This exam consists of **2** pages.

1. [5 marks]
Consider a heterojunction diode with a p-$Al_{0.3}Ga_{0.7}As$ region, and an n^+-GaAs region.
Sketch the equilibrium energy band diagram for this diode.
A vertical scale of $2\,\mathrm{cm} \equiv 1\,\mathrm{eV}$ is recommended for showing E_l, E_C and E_V with respect to E_0. The position of E_F with respect to the band edges need only be approximate. The horizontal scale also need only be approximate.

2. [5 marks]
The E-k relationships for the conduction bands of two semiconductor materials, A and B, each with spherical constant-energy surfaces, can be expressed as
$E_A - 0.7 = \alpha k^2$ and $E_B - 1.4 = 2\alpha(k - k')^2$,
respectively, where α is a constant, $k' > 0$, and the energies are in units of eV.
Both materials have the same valence-band structure, with the top of the valence band at E=0 and k=0.
Giving reasons for your answers, which material would:
(a) have the higher intrinsic carrier concentration?
(b) have the higher drift current at a given electric field and doping concentration?
(c) make the better solar cell?
(d) make the better LED?

3. [3 marks]
A photovoltaic module is made by connecting two identical solar cells in series. Ignore series resistance.
A shadow falls across one of the cells so that some significant fraction of its top surface is obscured.
This leads to a loss of power at the load, but it also leads to the serious possibility of the shadowed cell burning out.
Explain why the temperature is likely to rise in the shadowed solar cell.

More questions are on the back of this page.

4. [3 marks]

(a) Electrons propagating through periodic structures can be represented by Bloch functions.
Show that these functions properly account for the fact that an electron must have equal probability of being in any of the identical primitive unit cells in a perfectly crystalline material.
(b) Fig. 2.9b of the course notes shows the valence band of a semiconductor with an unoccupied state below the top of the band. Draw this plot and label the electron at the top of the band as electron 'A'.
Re-draw the plot for the situation at some short time Δt after a positive electric field $\mathcal{E}_x$ has been applied, and identify the new k-state of electron 'A'.
Give your reasoning for the new position of this electron in k-space.

5. [5 marks]

(a) Fig. 3.12 of the course notes shows an Auger recombination event involving two electrons and one hole. Re-draw Figs. 3.12a and 3.12b for the case of an Auger recombination event involving one electron and two holes.
(b) Eqn. (3.17) of the course notes is supposed to be proportional to the net rate of radiative recombination in a semiconductor.
Write down a correct version of the first line of this equation.
(c) Fig. 8.5 of the course notes shows the radiative recombination efficiency of a GaAs LED as a function of excess carrier concentration in the active layer. Auger recombination is not significant in this case.
Choose a value of Δn appropriate for low-level injection, and then use the values for A and B in Table 3.1 of the course notes to estimate η_{rad}.
Your answer should be significantly different from the correct answer, which is given by the lower curve of Fig. 8.5. This suggests that there is a typographical error in the value for A_e in Table 3.1.
Suggest the correct value for A_e.

6. [4 marks]

Fig. 7.7 shows the spectral photocurrent density for a Si np-junction solar cell. The thicknesses of the emitter and base regions are 200 nm and 450 μm, respectively. The front and back surface recombination velocities are 100 cm/s for holes and zero for electrons, respectively.
State what effect, if any, changing these values of surface recombination velocity would have on the photocurrent.
Give the reasoning behind your answer.