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

MID-TERM EXAM, October 20, 2011

Time: 1.25 hours
Notes, books and simple calculators are allowed.
Data-storage- or telecommunication-devices are not allowed.
This exam consists of **2** pages. Page 2 has to be handed-in with your exam paper.

1. [7 marks]
Consider a semiconductor for which the hole-energy *E-k* relationship for the valence band can be expressed as $E_h - 0.7 = 3\alpha k^2$,
and the electron-energy *E-k* relationship for the conduction band is given by $E_e - 0.7 = \alpha(k - k')^2$,
where $k' > 0$, α is a constant and the energies are in units of eV.
(a) Sketch the energy band structure, and the energy band diagram.
(b) A solar cell with a thin, heavily doped emitter and a thick, lightly doped base is to be made from this semiconductor material. Should the emitter be *n*-type or *p*-type? Give reasons for your answer.
(c) Generally in solar cells, why is the base lightly doped?

2. [6 marks]
Fig. 1 shows a band diagram from *Bandprof* for a forward-biassed *np* diode. The numbers on the figure are energy levels in meV. Some material parameters are given in the caption.
(a) Which side of the diode (*n*-side or *p*-side) is the more heavily doped?
(b) Estimate the applied bias voltage and the built-in voltage.
(c) Estimate the doping density in the *p-side* of the diode.
(d) Estimate the minority carrier concentration at the beginning of the *p*-QNR.

3. [7 marks]
(a) Derive an expression for the electron concentration as a function of position in the *p*-QNR of a forward-biassed, **ideal diode**.
(b) Using your expression for $n_p(x)$ from (a) above, show that the electron quasi-Fermi level should decrease linearly with distance over some part of the *p-QNR*, *i.e.*, when $n_p(x) \gg n_{0p}$.
(c) There is no recombination in the diode used in the Bandprof example in Question 2. However, if we now take the electron minority carrier diffusion length to be $0.1\,\mu$m in the *p*-QNR, sketch how E_{Fn} would change in the *p-QNR*.
Please mark your sketch directly on Figure 1, put your name on it, and attach it to your exam paper.
You don't need to do a detailed evaluation, but please show the reasoning for your answer.

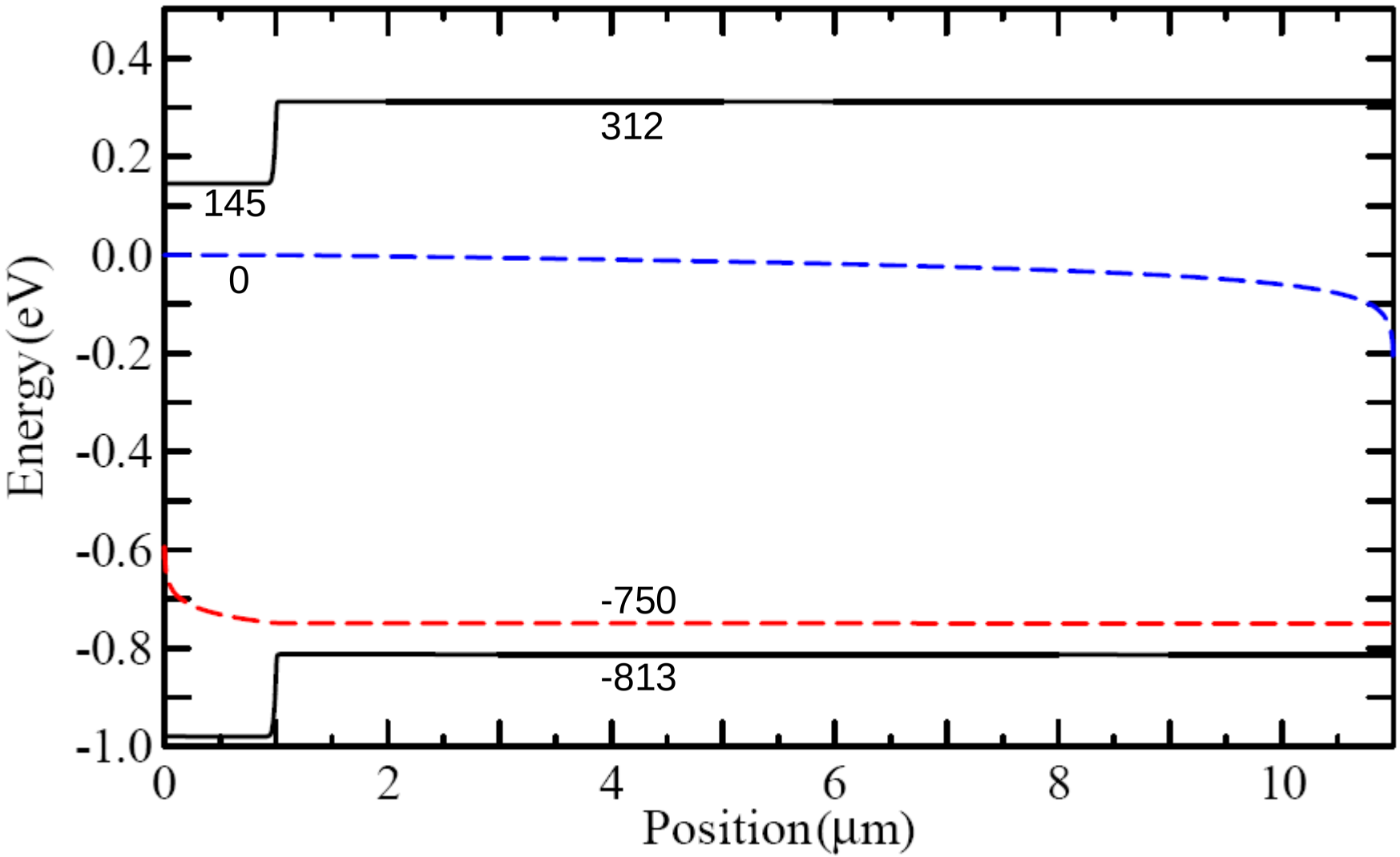

Figure 1: Energy band diagram (E_C, E_V, E_{Fn}, E_{Fp}) for a forward-biassed diode with no recombination. $N_C = 2.744 \times 10^{19}\,\mathrm{cm}^{-3}$, $N_V = 1.142 \times 10^{19}\,\mathrm{cm}^{-3}$, $k_B T = 25.9\,\mathrm{meV}$ at $T = 300\,\mathrm{K}$.