Department of Electrical and Computer Engineering
UNIVERSITY OF BRITISH COLUMBIA

EECE 480 MICROELECTRONIC DEVICES

MID-TERM EXAM, October 27, 2005

Time: 1.25 hours
Full marks can be obtained by answering Questions 1 and 2 correctly.
No notes, programmable calculators or books allowed.
This exam consists of 1 sheet.
Some equations are given on the back of the sheet.

1. Use the top half of a page for part (a) of this question, and the bottom half of the same page for part (b). Please make your diagrams easy to read. Align the two figures so that they share the same distance axis. Show the edges of the conduction and valence bands, the quasi-Fermi levels, and the widths of the depletion regions in the emitter, base and collector.
(a) [10 marks] Sketch the energy band diagram for a **p^+-n-p** BJT operating in the normal, active mode.
(b) [5 marks] Repeat the above, but for the same transistor operating in the normal, saturation mode.
(c) [5 marks] Draw the large-signal (Ebers-Moll) equivalent circuit for the transistor operating as in Question 1(b). Use the IEEE convention for current.
(d) [5 marks] Explain the physical process that is represented by the capacitors that appear in the large-signal equivalent circuit.

2. A West-coast start-up, *480 Semiconductor Inc.*, hires two device engineers, Juliet and Zoe, to design a high-β, n^+-p-n BJT that is to operate at $V_{BC} = 0$.
Both designers agree:
- on the doping densities in the base and the collector;
- that the emitter should be essentially infinitely long;
- that the base should be so short that there is essentially no recombination in this region;
- that the doping-density dependence of the minority-carrier properties in the emitter is not important.

Each designer comes up with a transistor that has the same gain, but Zoe's device has a quasi-neutral-basewidth that is twice as long as that of Juliet's device.
(a) [10 marks] Determine the ratio of the emitter doping densities of the two transistors.
(b) [15 marks] The Head Designer, Bill Shockley Jr., decides that the company will go with the transistor that has the higher $f_{\max}$. He systematically goes through the factors that affect this figure of merit, and makes his choice. Please do the same.

3. [Bonus] Show that the hole current density injected into the very long (essentially infinite) n-region of a p-n junction under forward bias V_A can be written as

$$J_h(0) = q\frac{D_h}{L_h}p_{0n}\left(e^{\frac{qV_A}{kT}} - 1\right) . \tag{1}$$