ECE 606 Exam 4: Spring 2013
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This is a closed book exam. You may use a calculator and the formula sheet at the end of this exam.

There are four equally weighted questions. To receive full credit, you must show your work (scratch paper is attached).

The exam is designed to be taken in 60 minutes, but you may use the full, 75 minute class period.

Be sure to fill in your name and Purdue student ID at the top of the page.

DO NOT open the exam until told to do so, and stop working immediately when time is called.

40 points possible, 10 per question

1) 2 points for each part – 10 points total

2) 2 points for each part – 10 points total

3a) 4 points
3b) 2 points
3c) 2 points
3d) 2 points

4) 2 points for each part – 10 points total
Answer the **five multiple choice questions** below by choosing the **one, best answer**.

1) What can we determine from a plot of one over junction capacitance squared vs. reverse bias voltage?
   a) The minority carrier lifetime.
   b) The minority carrier diffusion coefficient.
   c) The semiconductor bandgap.
   d) The doping density.
   e) The series resistance.

2) When is the diffusion capacitance important?
   a) For low DC forward bias and for frequencies that are well below \(1/(2\pi \tau_n)\).
   b) For low DC forward bias and for frequencies that are well above \(1/(2\pi \tau_n)\).
   c) For high DC forward bias and for frequencies that are well below \(1/(2\pi \tau_n)\).
   d) For high DC forward bias and for frequencies that are above \(1/(2\pi \tau_n)\).
   e) For low DC forward bias and for frequencies that are well below \(1/(2\pi \tau_n)\).

3) There are two PN junctions in a bipolar transistor. Each one can be either forward biased (FB) or reverse biased (RB). In the “saturation” region of operation, how are these two junctions biased?
   a) Emitter-base is FB and base-collector is FB.
   b) Emitter-base is FB and base-collector is RB.
   c) Emitter-base is RB and base-collector is FB.
   d) Emitter-base is RB and base-collector is RB.
   e) Emitter-base is zero-biased and base-collector is zero-biased.

4) The increase in collector current as the magnitude collector voltage increases is known as the Early effect and is due to what physics?
   a) Quantum mechanical tunneling.
   b) Impact ionization.
   c) SRH recombination
   d) The decreasing width of the quasi-neutral base.
   e) Generation in the space charge region.

5) To achieve a high common emitter current gain, \(\beta_{DC}\), the base of an NPN silicon BJT **must** be doped much less heavily than the emitter. Why?
   a) To minimize recombination in the emitter-base junction.
   b) The minimize recombination in the base.
   c) To minimize current crowding in the base.
   d) To put the base in high-level injection.
   e) To increase the ratio of the electron current injected into the base and the hole current injected into the emitter.
2) Consider an NPN BJT with the following parameters:

\[
I_{E_n} = 2 \text{ mA} \quad I_{E_p} = 0.01 \text{ mA} \quad I_{C_n} = 1.98 \text{ mA} \quad I_{C_p} = 0.0001 \text{ mA}
\]

2a) Determine the base transport factor, \( \alpha_T \).

2b) Determine the emitter injection efficiency, \( \gamma \).

2c) Determine the current, \( I_E \).

2d) Determine \( \alpha_{DC} \).

2e) Determine \( \beta_{DC} \).
3) **Sketch** the minority hole concentration in the base of a PNP BJT for the following conditions. In each case, **indicate the magnitude** of $\Delta \rho$ at $x = x_n$ and at $x = x_n + W_B$.

3a) **Forward active region.**

![Forward active region diagram]

3b) **Inverted active region.**

![Inverted active region diagram]
3c) Saturation

\[ \Delta \rho(x) \]

\[ x = x_n \quad x = x_n + W_g \]

3d) Cut-off

\[ \Delta \rho(x) \]

\[ x = x_n \quad x = x_n + W_g \]
4) Consider the impact of changing some key BJT device parameters on some key figures of merit. For each of the 5 changes below, explain in words whether the change increases, decreases, or has no effect on the current gain, $\beta_{DC}$. Assume negligible recombination in the base and emitter.

4a) Double the width of the quasi-neutral base.

4b) Double the base lifetime.

4c) Double the base doping.

4d) Double the width of the quasi-neutral emitter.

4d) Double the emitter doping.
SCRATCH PAPER