EHB222E Introduction to Electronics

MIDTERM I

Duration: 120 Minutes
Grading: 1) 15%, 2) 30%, 3) 25%, 4) 30%
Exam is in closed-notes and closed-books format; calculators are allowed.
For your answers please use the space provided in the exam sheet.

GOOD LUCK!

1. The current-voltage equation of a p-n diode is given as
   \[ I_D = I_S \left( e^{V_D/nV_T} - 1 \right) \]
   where
   \[ I_S = A q n_i^2 \left( \frac{D_p}{L_p N_D} + \frac{D_n}{L_n N_A} \right) \]
   Additionally, \[ L_p = \sqrt{D_p \tau_p} \] and \[ L_n = \sqrt{D_n \tau_n} \].

   The diode conducts current of \(-10^{-15}\)A when -3V voltage applied.
   Determine the \textbf{junction area} \( A \) with a unit of \( \mu m^2 \).

Parameters: \( n_i = 2.5 \times 10^{10} / cm^3 \), \( N_D = 10^{17} / cm^3 \), \( N_A = 10^{15} / cm^3 \), \( q = 1.6 \times 10^{-19} \) C, \( 1 \leq n \leq 2 \),
\( V_T = 25 \) mV, \( D_n = 100 \) cm²/s, \( D_p = 16 \) cm²/s, \( \tau_n = \tau_p = 1 \) μsec.
2. For the diodes, use the models shown below; the regular diode model has 0.7V forward bias voltage; the Zener diode model has -3V breakdown voltage.
   a. Determine the minimum positive value of $I_{in}$ to make $D_1$ conduct current.
   b. Determine the minimum positive value of $I_{in}$ to make $D_2$ conduct current.
   c. Sketch $V_{out}$ versus $I_{in}$ ($0 \leq I_{in} \leq 10mA$).
3. Consider a voltage source shown below. It drives a load with a minimum value of 100Ω; \( R_Y \geq 100\Omega \). Its output voltage should be around 3.3V; \( V_Y \approx 3.3V \). Determine the maximum value of \( R_1 \).

\[ \text{Transistor parameters: } V_{BE} = 0.7, \beta = 100, V_A = \infty. \]
For the circuit shown below, suppose that all of the transistors are in forward active region; $|V_{BE}| = 0.7\,\text{V}$, $\beta = 200$, and $|V_A| = \infty$ for all transistors.

a. If $V_i = 0\,\text{V}$, determine the values of $I_{C_1}$, $I_{C_2}$, and $I_{C_3}$.

b. If $V_i = 0\,\text{V}$ and $I_{C_4} = 0.5\,\text{mA}$, determine the value of $R_{E_4}$. 

\[ I_{C_1} + I_{C_2} + I_{C_3} = 0.5\,\text{mA} \]