NAME:_____

Department of Electrical and Computer Engineering
Fall 2023 BREADTH EXAM

TTG Area: Circuits and Systems **ECGR-4134 Solid State II**
Ten problems at 10 points each:

All problems assume a silicon npn bipolar transistor. Given the following information:

$n_{B0} = \frac{n_i^2}{N_B}$; $V_t = 0.0259\ V$; $p_{E0} = \frac{n_i^2}{N_E}$;

$V_{bi} = V_t ln \frac{N_a N_d}{n_i^2}$

$L_E = \sqrt{D_E \tau_{E0}}$; $L_B = \sqrt{D_B \tau_{B0}}$

$\alpha_T = \frac{1}{cosh\left(\frac{x_B}{L_B}\right)}$; $\gamma = \frac{1}{1+\frac{p_{E0} D_E L_B}{n_{B0} D_B L_E} tanh\left(\frac{x_B}{L_B}\right)}$;

$J_{s0} = \frac{q D_B n_{B0}}{L_B tanh\left(\frac{x_B}{L_B}\right)}$; $\alpha = \gamma \alpha_T \delta$; $\beta = \frac{\alpha}{1-\alpha}$;

$\delta = \frac{1}{1+\frac{J_{r0}}{J_{s0}} exp\left(\frac{-qV_{BE}}{2kT}\right)}$; $q = 1.6x10^{-19} C$; $p_{E0} = \frac{n_i^2}{N_E} exp\left(\frac{-\Delta E_g}{kT}\right)$; $T = 300K$,

$\varepsilon_0 = 8.85x10^{-14} F/cm$;

$\varepsilon_s = 11.7\varepsilon_0$; $E_g = 1.12\ eV$, $N_E = 10^{18} cm^{-3}$;
$N_B = 10^{16} cm^{-3}$; $D_E = 15\ cm^2/s$;

$D_B = 8\ cm^2/s$; $\tau_{E0} = 3x10^{-7} s$;

$\tau_{B0} = 2x10^{-7} s$; $x_E = 0.5\ \mu m$; $x_B = 0.7\ \mu m$;
$V_{BE} = 0.65\ V$; $J_{r0} = 5x10^{-8} A/cm^2$

$\Delta n_B(x) = \frac{n_{B0}\left\{\left[exp\left(\frac{qV_{BE}}{kT}\right)-1\right] sinh\left(\frac{x_B - x}{L_B}\right) - sinh\left(\frac{x}{L_B}\right)\right\}}{sinh\left(\frac{x_B}{L_B}\right)}$

$n_i = 1.5x10^{10} cm^{-3}$

1- What is the thermal equilibrium minority carrier hole concentration in the emitter without the band-gap narrowing effect?
2- What is thermal equilibrium minority carrier hole concentration considering the band-gap narrowing effect in the emitter as doping changes from 10^{18} cm^{-3} to 10^{19} cm^{-3}? (Assume band-gap change from 0.030 eV to 0.080 eV)
3- What is the thermal equilibrium carrier electron concentration in the base?
4- What is the excess carrier electron concentration in the base at *x = 0*?
5- What is the emitter injection efficiency factor?
6- What is the base transport factor?
7- What is the reverse saturation current density?
8- What is the recombination factor?
9- What is the common-base current gain?
10- What is the common emitter current gain?