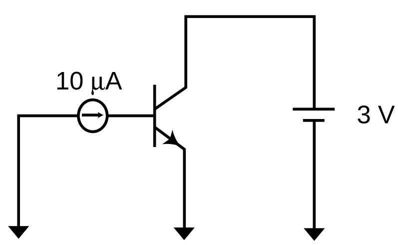
Homework #9 - December 2, 2002

Due: December 6, 2002 at lecture

1. *[35 points]* Consider a bipolar transistor with the following large-signal equivalent circuit model parameters $I_S = 10^{-16}\ A$, $\beta_F = 100$, and $\beta_R = 1$. To answer some of the following questions, use the non-linear hybrid-π model of the transistor presented in class.

□ Answer the following questions when the device is biased as sketched in the diagram below:

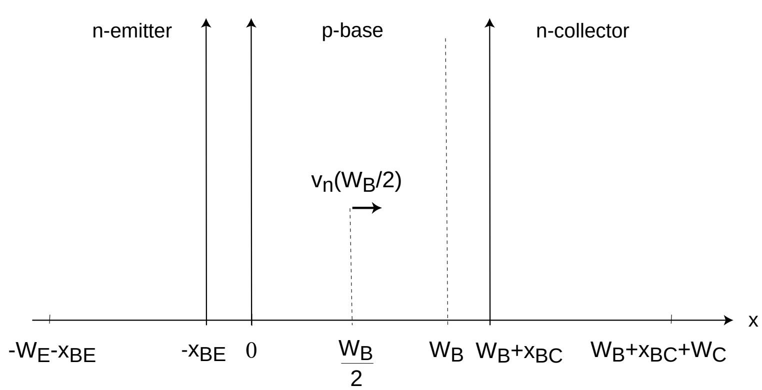


a) In what regime is the device operating? Explain.

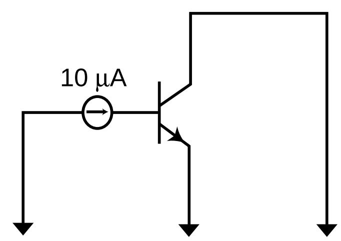
b) Calculate the collector current, I_C.

c) Calculate the base-emitter voltage V_{BE}.

d) If the doping level in the base is $N_B = 10^{17}\ cm^{-3}$ and the area of the base-emitter junction is $A_E = 40\ \mu m^2$, calculate the electron velocity in the middle of the quasi-neutral base (see sketch below).



□ Answer the following questions when the device is biased as sketched in the diagram below:

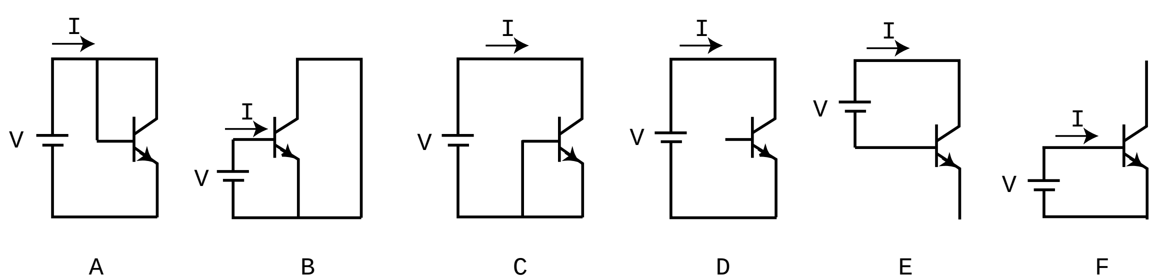


e) In what regime is the device operating? Explain.

f) Calculate the base-emitter voltage V_{BE}.

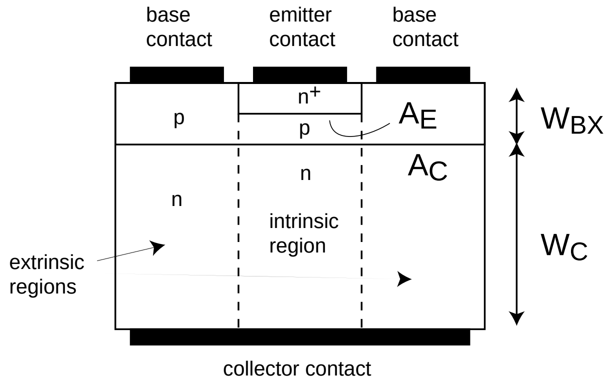
g) Calculate the collector current, I_C.

2. *[35 points]* The figure below shows six possible ways of connecting an npn bipolar transistor that may yield a diode-like behavior. Using the ideal *Non-Linear Hybrid-π Model*, calculate the I-V characteristics of the two-terminal device in each configuration. Express your result as a function of I_S, β_F, and β_R.



Which of these configurations exhibit diode-like I-V characteristics?

3. *[30 points]* This problem is about deriving expression for β_R and τ_R for an ideal BJT. Consider the cross-section of an ideal BJT where the thickness of the base in the extrinsic region is labeled as W_{BX} and the thickness of the collector is labeled as W_C. Use the usual symbols for all other parameters.



Consider this BJT ideal in all regards as defined in Ch. 11 of the notes. This BJT is biased in the reverse regime.

a) In the reverse regime, identify and derive expressions for all components of I_B in terms of structural paremeters of the device and V_{BC}.

b) Derive an expression for β_R in terms of the structural parameters of the device.

c) Evaluate the order of β_R under the following assumptions: $N_B \simeq 10N_C$, $A_C \simeq 10A_E$, $W_C \simeq 10W_B$, $W_{BX} \simeq 2W_B$, and $D_B \simeq D_C$.

d) Identify all components of Q_R, the minority carrier stored charge everywhere in the device in the reverse regime. Express your result in terms of V_{BC}, the structural parameters of the device, and the appropriate minority carrier transit times defined in the table below:

region	*minority carrier transit time*
emitter	τ_{tE}
base	τ_{tB}
extrinsic base	τ_{tBX}
collector	τ_{tC}

e) Derive an expression for τ_R in terms of the appropriate minority carrier transit times and other structural parameters of the device.