1. a) Forward Active  
   EB fwd. bias  
   CB rev. bias  

   b) Cutoff  
   both junctions rev. bias  

Saturation
\[ D_E = \frac{kT}{2} \mu (N_E = 5 \times 10^{17}) = (0.26)(420 \text{ cm}^2 / \text{V.s}) \]
\[ D_E = \frac{10.9}{5} \text{ cm}^2 \]

\[ D_B = \frac{kT}{2} \mu (3 \times 10^{16}) = (0.26)(350 \text{ cm}^2 / \text{V.s}) \]
\[ D_B = \frac{9.1}{5} \text{ cm}^2 \]

\[ D_C = \frac{kT}{2} \mu (6 \times 10^{15}) = (0.26)(1290 \text{ cm}^2 / \text{V.s}) \]
\[ D_C = \frac{33.5}{5} \text{ cm}^2 \]

\[ L_E = \sqrt{D_E \cdot T_E} = 14.8 \mu m \quad L_B = 13.5 \mu m \]
\[ L_C = 58 \mu m \]

What is \( W \)?

\[ W = W_B - X_{AE} - X_{AC} \]

\[ V_{EB} = 1.3 \text{ V} \]

\[ X_{AE} = \sqrt{\frac{2e}{k} (V_b - V_o) \frac{N_a}{N_a (N_a + N_d)}} \]

\[ V_{B_o} = \frac{kT}{2} \ln \frac{N_a N_d}{n_i^2} = 0.84 \]

\[ X_{AE} = 0.15 \mu m \]
$V_{c_0} = -3V$

$$X_{dc} = \sqrt{\frac{2e}{2} (V_b - V_a) \frac{N_a}{N_d (N_a + N_d)}}$$

$$V_b = \frac{kT}{2} \ln \frac{N_a N_d}{n_i^2} = 0.73$$

$$X_{dc} = 0.16 \mu m$$

$$W = 1.6 \mu m - 0.15 \mu m - 0.16 \mu m$$

$$W = 1.29 \mu m$$

In forward active

$$I_E = 9n_i^2 A \left( \frac{D_E}{LEKE} + \frac{D_B}{WNB} \right) e^{\frac{V_{EB}}{kT}}$$

The emitter injection efficiency

$$\gamma = \frac{I_{EP}}{I_{E0} + I_{EP}}$$

$$\gamma = \frac{D_B}{WNB} \frac{D_B}{LEKE + \frac{D_B}{WNB}} = 0.994$$
\( d_T = \text{base transport factor} \)

\[ d_T = 1 \text{ in absence of base recombination} \]

\[ d_T = 1 - \frac{W^2}{2L_b} \rightarrow \text{With base recombination} \]

\[ d_T = 0.995 \]

\[ \beta = \frac{d_T \gamma}{1 - d_T \gamma} = 142 \text{ with no base recombination} \]

\[ \beta = 83 \text{ with base recombination} \]

**Inverse active:** use same \( W \)

\[ \gamma = \frac{D_b}{W N_b} \]

\[ \frac{D_c}{L_c N_c} + \frac{D_b}{W N_b} = 0.71 \]

\[ d_T = 1 \text{ with no base recombination} \]

\[ \beta = 2.45 \]
The primary reason that $\gamma$ & $\beta$ have changed is due to the doping differences between the emitter & collector.

Since the $N_{e_p} \gg N_{e_n}$ hole current dominates the forward biased EB junction.

However, since $N_{e_p} \ll N_{e_n}$, electron current is much more important & thus offsets the contribution due to the small size of the base.