1. In class, we have discussed EM-BJT models for vertical \textit{npn}-BJTs. In this problem you will develop EM1 and EM2 models for lateral PNP transistors.
   (a) Sketch the basic EM1 model for lateral \textit{pnp}-BJTs.
   (b) Write down the expressions for EM1 terminal currents (I_E and I_C)
   (c) Include the bulk-ohmic resistors and charge storage elements in EM1 model to generate EM2 model for lateral \textit{pnp}-BJTs.
   Justify any assumptions you make.


3. As we discussed in class, the base transit time for an \textit{npn}-BJT in EM2 model is a limiting factor for minority-carrier diffusion-charge forward transit time:
   (a) Show that the forward base transit time is given by:
   \[ \tau_B \cong \frac{W_B^2}{2D_n} \]
   (b) Calculate \( \tau_B \) for a device with 1 \( \mu \)m base width and \( D_n = 15 \text{ cm}^2/\text{sec} \).
   (c) If an \( \varepsilon \) field is present in the base (due to an impurity gradient, for example), the electrons will move partially by drift. Assuming a constant \( \varepsilon \) field, how much voltage drop across the base would be required to produce a transit time due to drift alone, equal to the \( \tau_B \) calculated in (a)?
   (d) We discussed in EM3 model that in the normal active mode of an \textit{npn}-BJT operation, the base-width modulation due to reverse-biased base-collector voltage (\( V_{BC} \)) is modeled by a parameter \( V_A \) called the forward \textit{Early voltage}. Show that \( \tau_B \) due to base-width modulation in EM3 model can be described by:
   \[ \tau_B(V_{BC}) = \tau_B(0) \left( 1 + \frac{V_{BC}}{V_A} \right)^2 \]

4. (a) Compare EM1, EM2, and EM3 BJT models. Tabulate the model parameters and their advantages and deficiencies for each EM-model.
   (b) Show how SGP-model improves BJT-device characterization.