- ***Any value of R_C higher than 4.3 kΩ would push Q in saturation***
- Choose R_C = 20 kΩ:
  - Assuming ***FA*** operation is maintained, V_{CE} comes out to be –15 V!
  - ***Golden rule***:
    - ***Potential at any point in a circuit can never go beyond the positive and negative extremes of the power supply voltages, unless there is a power source within the circuit***
  - Thus, V_{CE} = –15 V is ***absurd***!
  - Hence, Q is ***no more*** in the ***FA*** mode of operation, rather it has been pushed into ***saturation***

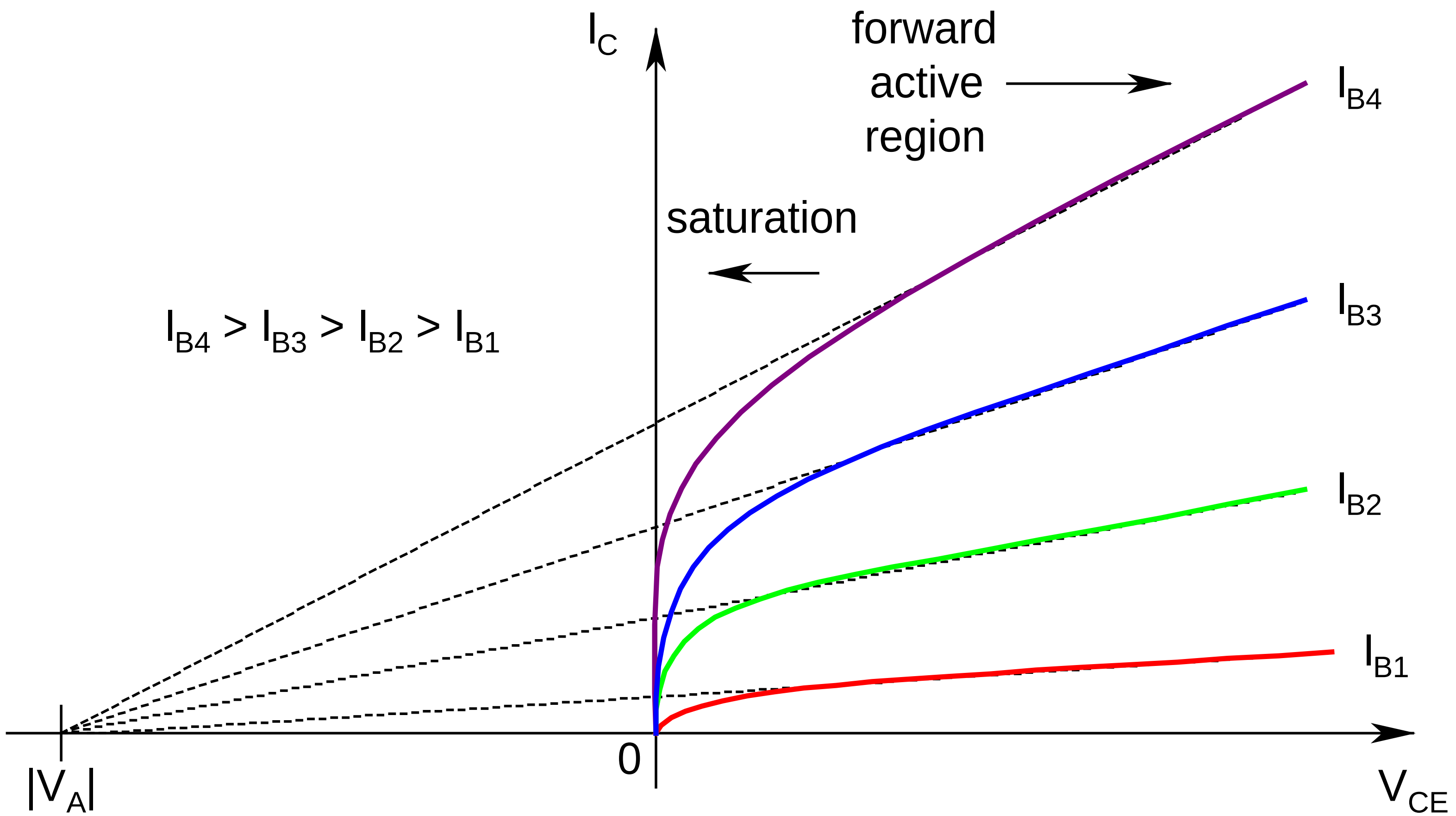
- Whether it is in ***soft saturation*** (SS) or ***hard saturation*** (HS), would ***depend*** on the ***degree of saturation*** (DoS)
- ***For HS, DoS must be ≥ 2*** ($\beta_{sat} \leq \beta/2$)
- Assume ***HS***: V_{BE}(HS) = 0.8 V, V_{CE}(HS) = 0.1 V
  - ❖ $I_{B,sat} = [V_{CC} - V_{BE}(HS)]/R_B = (5 - 0.8)/(430\ k\Omega) = 9.77\ \mu A$
  - ❖ $I_{C,sat} = [V_{CC} - V_{CE}(HS)]/R_C = (5 - 0.1)/(20\ k\Omega) = 245\ \mu A$
  - ❖ $\beta_{sat} = I_{C,sat}/I_{B,sat} = 245/9.77 = 25$
  - ❖ DoS = $\beta/\beta_{sat} = 4\ (> 2)$
  - ❖ ***Assumption verified, and analysis is correct***!

➢ **Ex.**: Find the values of R_C that would put Q at the edge of: i) HS, and ii) SS

Base Width Modulation Effect

- In ***FA*** mode, as $|V_{BC}|\uparrow$, BC ***depletion region width***$\uparrow \Rightarrow$ ***neutral base width***$\downarrow$
  - ➢ ***Electrons spend less time in base*** $\Rightarrow$ ***chance of recombination***$\downarrow$
  - ➢ ***More electrons make it to the collector*** $\Rightarrow I_C\uparrow$ as $V_{CE}\uparrow$
  - ➢ Known as the ***Base Width Modulation Effect*** (or ***Early Effect***)

- The ***current-voltage characteristic***, including ***Early Effect***, is modeled as:
  - $I_C = I_S[\exp(V_{BE}/V_T)](1 + V_{CE}/V_A)$
  - V_A: ***Early Voltage*** (~ 130 V for ***npn***, and ~ 52 V for ***pnp***)
  - V_A is a ***negative number***, but taken to be a ***positive quantity***
- Imparts a ***positive slope*** in the ***output characteristics*** in the ***FA region***
  - Introduces an ***output resistance***, and makes the current source ***non-ideal***!



All characteristics merge at $|V_A|$ in the negative V_{CE} axis

Note: If $V_A \rightarrow \infty$, all characteristics become horizontal in the FA region

IEEE Notational Convention

- ***Pure DC quantities***:
  - ***Capital letter with capital subscript*** (e.g., V_{BE})
- ***Pure ac quantities***:
  - ***Small-case letter with small-case subscript*** (e.g., v_{be})
- ***Instantaneous (DC + ac) quantities***:
  - Either ***capital letter with small-case subscript*** (e.g., V_{be}) or ***small-case letter with capital subscript*** (e.g., v_{BE})

Small-Signal Model

- The ***electrical equivalent*** of the BJT at the ***DC bias point***
- Basically an ***electrical network***, having ***passive and active elements***
- To obtain this model, ***DC analysis*** is needed, since the ***information*** regarding the ***Q-point*** (I_C, V_{CE}) is necessary
- ***This model for npn and pnp BJT is same***