BJT h-parameter (H.16)

20170518

References

Based

[1] Floyd, Electronic Devices 7th ed
[2] Cook,

[2] en.wikipedia.org

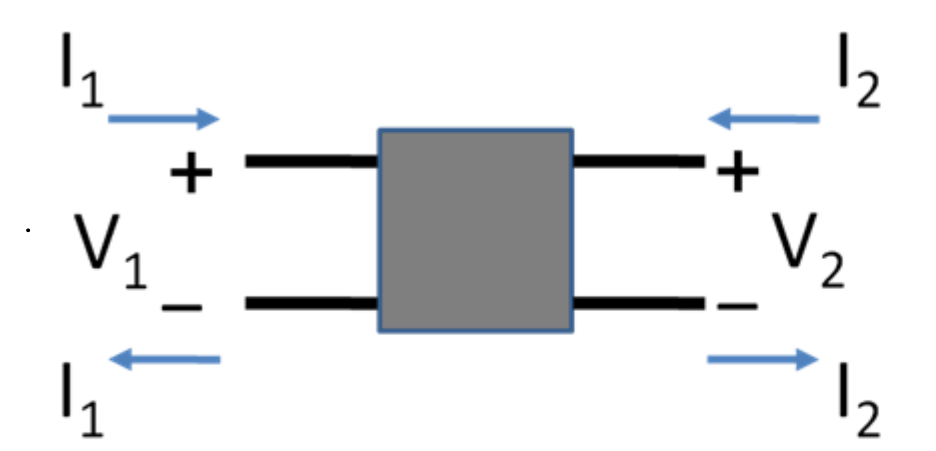

Figure 1: Example two-port network with symbol definitions.
Notice the port condition is satisfied:
the same current flows into each port as leaves that port.

https://en.wikipedia.org/wiki/Two-port_network#Hybrid_parameters_.28h-parameters.29

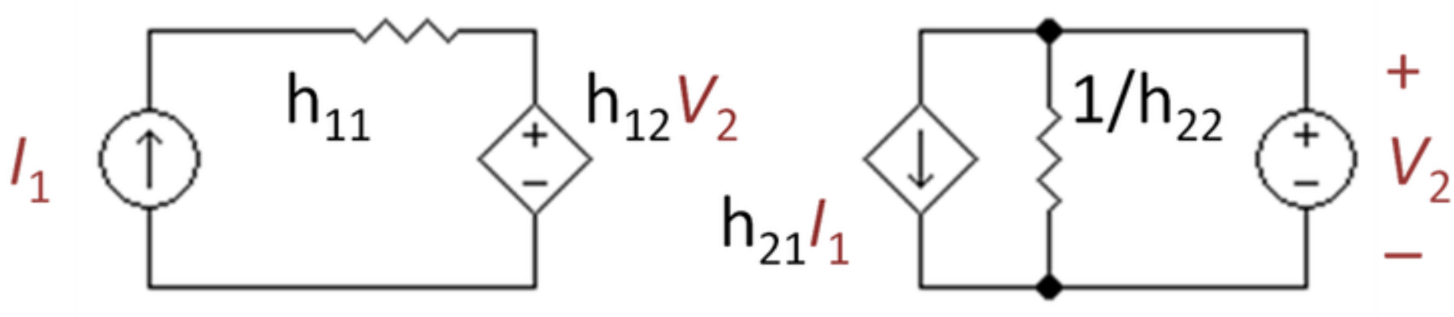

Figure 6: H-equivalent two-port showing independent variables I1 and V2; h22 is reciprocated to make a resistor

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$$\begin{bmatrix} V_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} h_{11} & h_{12} \\ h_{21} & h_{22} \end{bmatrix} \begin{bmatrix} I_1 \\ V_2 \end{bmatrix}$$

$$h_{11} \stackrel{\text{def}}{=} \left.\frac{V_1}{I_1}\right|_{V_2=0} \qquad h_{12} \stackrel{\text{def}}{=} \left.\frac{V_1}{V_2}\right|_{I_1=0}$$

$$h_{21} \stackrel{\text{def}}{=} \left.\frac{I_2}{I_1}\right|_{V_2=0} \qquad h_{22} \stackrel{\text{def}}{=} \left.\frac{I_2}{V_2}\right|_{I_1=0}$$

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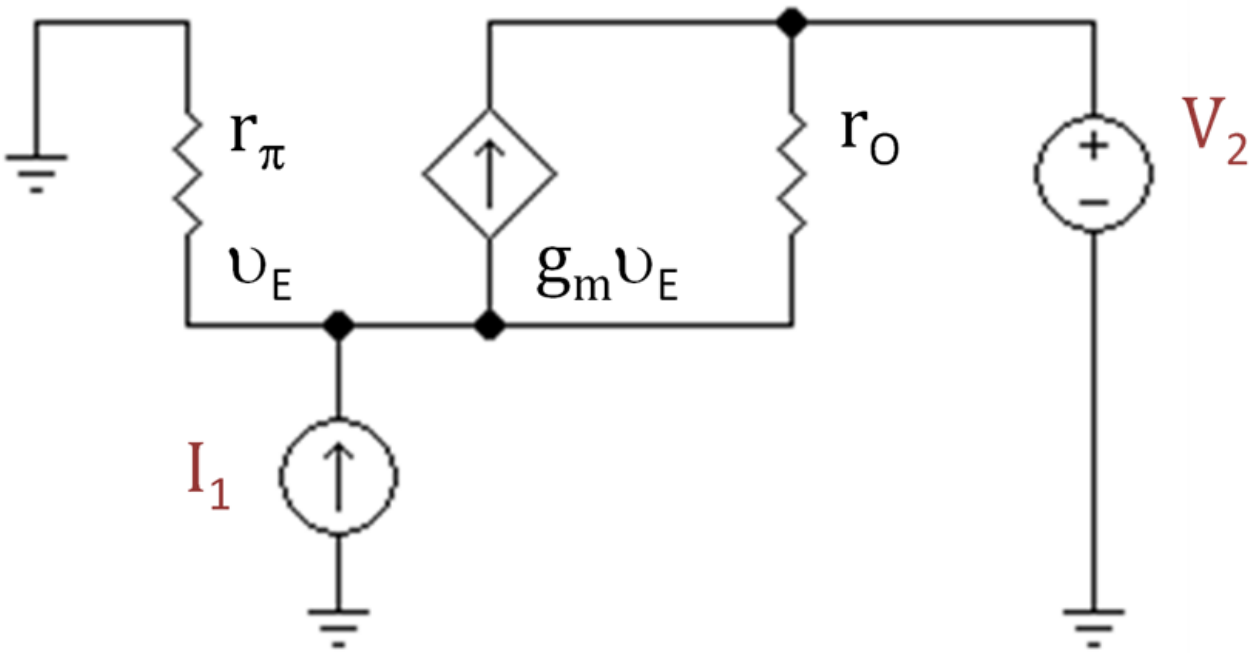


$$h_{21} = \left.\frac{I_2}{I_1}\right|_{V_2=0} \qquad -\frac{\frac{\beta}{\beta+1}r_O + r_\pi}{r_O + r_\pi} \qquad -\frac{\beta}{\beta+1}$$

$$h_{11} = \left.\frac{V_1}{I_1}\right|_{V_2=0} \qquad r_\pi \| r_O$$

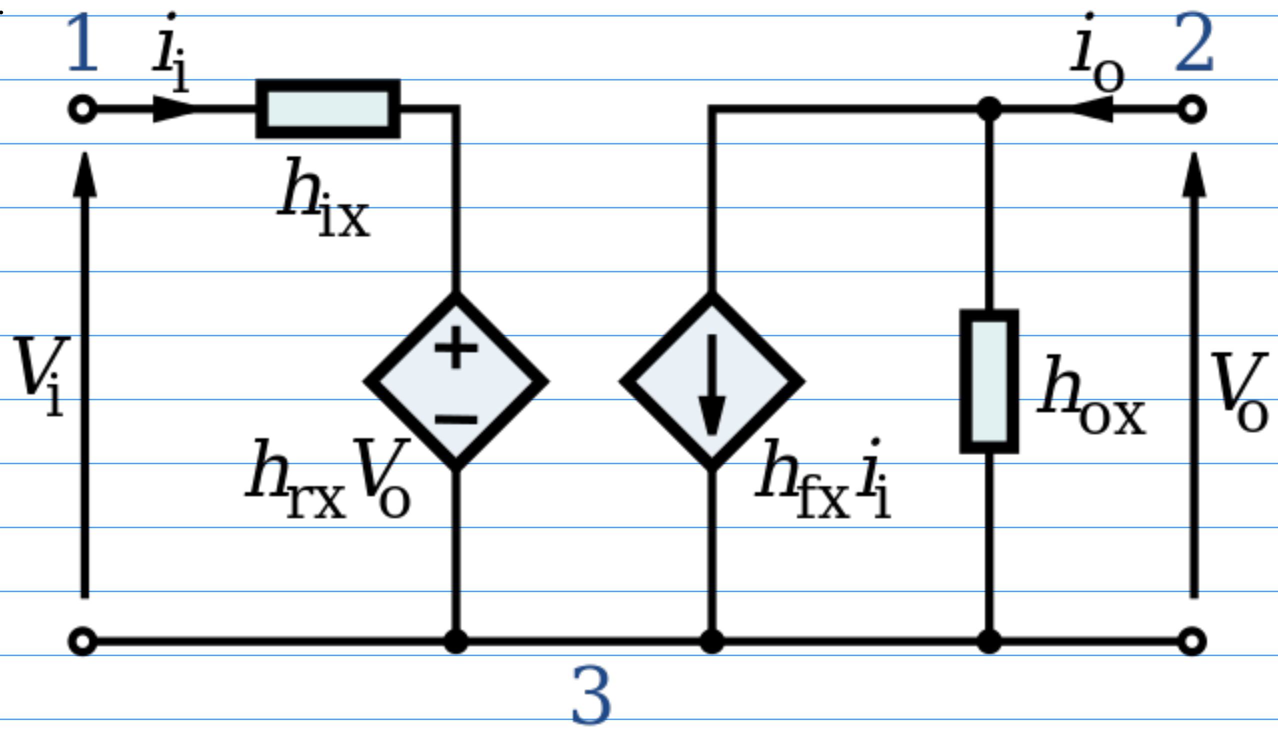
$$h_{22} = \left.\frac{I_2}{V_2}\right|_{I_1=0} \qquad \frac{1}{(\beta+1)(r_O + r_\pi)} \qquad \frac{1}{(\beta+1)r_O}$$

$$h_{12} = \left.\frac{V_1}{V_2}\right|_{I_1=0} \qquad \frac{r_\pi}{r_O + r_\pi} \qquad \frac{r_\pi}{r_O} \ll 1$$

The h-parameters were initially called series-parallel parameters.
The term hybrid to describe these parameters was coined by D. A.
Alsberg in 1953 in "Transistor metrology".[8]
In 1954 a joint committee of the IRE and the AIEE
adopted the term h parameters and recommended
that these become the standard method of testing and characterising transistors
because they were "peculiarly adaptable to the physical characteristics of transistors".[9]
In 1956 the recommendation became an issued standard; 56 IRE 28.S2.
Following the merge of these two organisations as the IEEE,
the standard became Std 218-1956 and was reaffirmed in 1980,
but has now been withdrawn.[10]

https://en.wikipedia.org/wiki/Bipolar_junction_transistor#h-parameter_model

h-parameter model



Another model commonly used to analyze BJT circuits is the h-parameter model, closely related to the hybrid-pi model and the y-parameter two-port, but using input current and output voltage as independent variables, rather than input and output voltages.
This two-port network is particularly suited to BJTs as it lends itself easily to the analysis of circuit behaviour, and may be used to develop further accurate models.
As shown, the term, x, in the model represents a different BJT lead depending on the topology used.
For common-emitter mode the various symbols take on the specific values as:

Terminal 1, base
Terminal 2, collector
Terminal 3 (common), emitter; giving x to be e
ii, base current (ib)
io, collector current (ic)
Vin, base-to-emitter voltage (VBE)
Vo, collector-to-emitter voltage (VCE)

and the h-parameters are given by:

- hix = hie, the input impedance of the transistor (corresponding to the base resistance rpi).

- hrx = hre, represents the dependence of the transistor's IB–VBE curve on the value of VCE. It is usually very small and is often neglected (assumed to be zero).

- hfx = hfe, the current-gain of the transistor. This parameter is often specified as hFE or the DC current-gain (βDC) in datasheets.

- hox = 1/hoe, the output impedance of transistor. The parameter hoe usually corresponds to the output admittance of the bipolar transistor and has to be inverted to convert it to an impedance.

As shown, the h-parameters have lower-case subscripts and hence
signify AC conditions or analyses. For DC conditions they are specified
in upper-case. For the CE topology, an approximate h-parameter model
is commonly used which further simplifies the circuit analysis.
For this the hoe and hre parameters are neglected
(that is, they are set to infinity and zero, respectively).
The h-parameter model as shown is suited to low-frequency,
small-signal analysis. For high-frequency analyses
the inter-electrode capacitances that are important
at high frequencies must be added.

Etymology of hFE
The h refers to its being an h-parameter, a set of parameters named for their origin in a hybrid equivalent circuit model.
F is from forward current amplification also called the current gain.
E refers to the transistor operating in a common emitter (CE) configuration.
Capital letters used in the subscript indicate that hFE refers to a direct current circuit.

https://www.onsemi.com/pub/Collateral/2N3903-D.PDF

TYPICAL STATIC CHARACTERISTICS

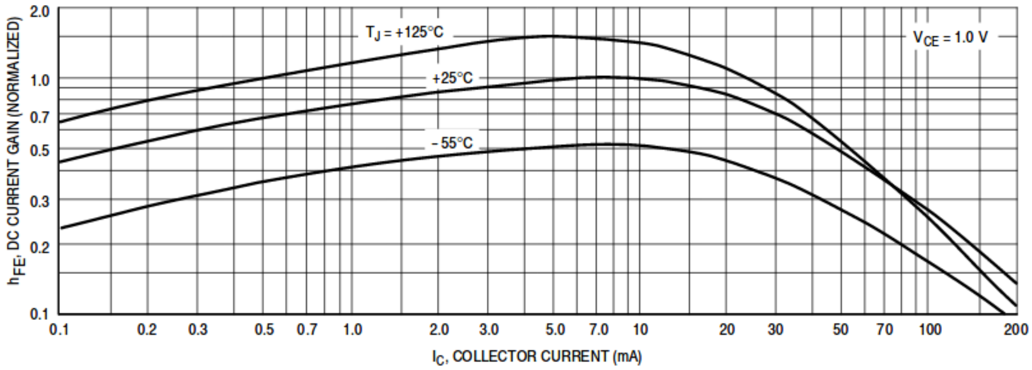
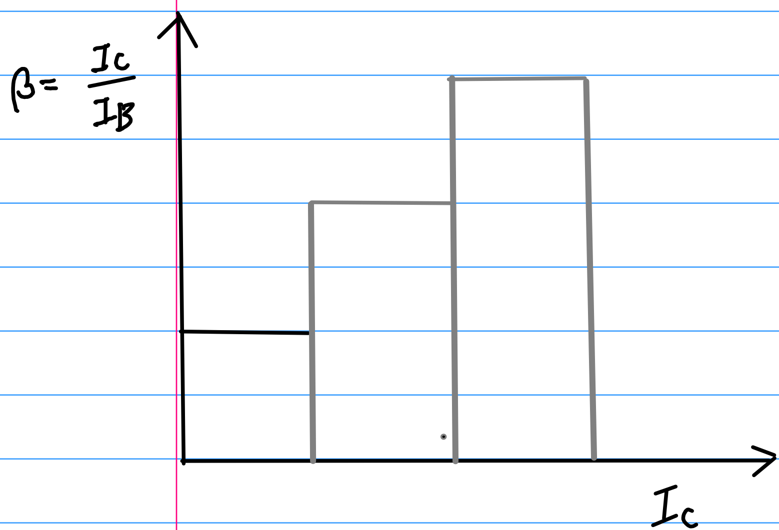
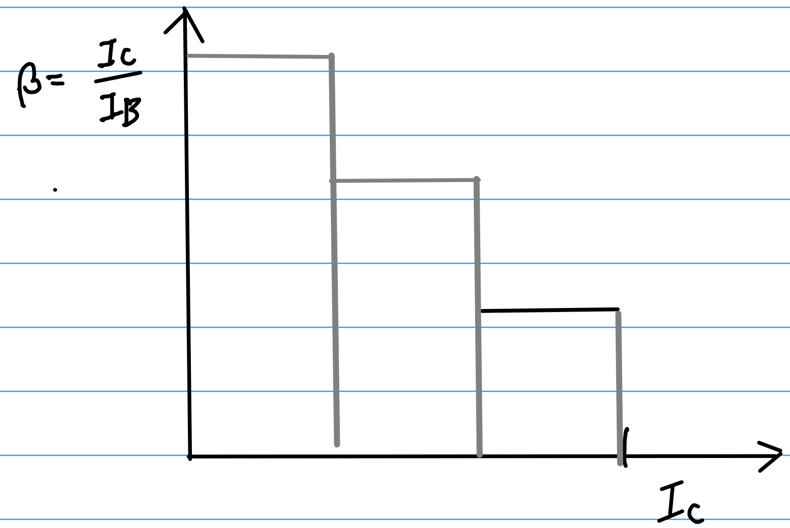
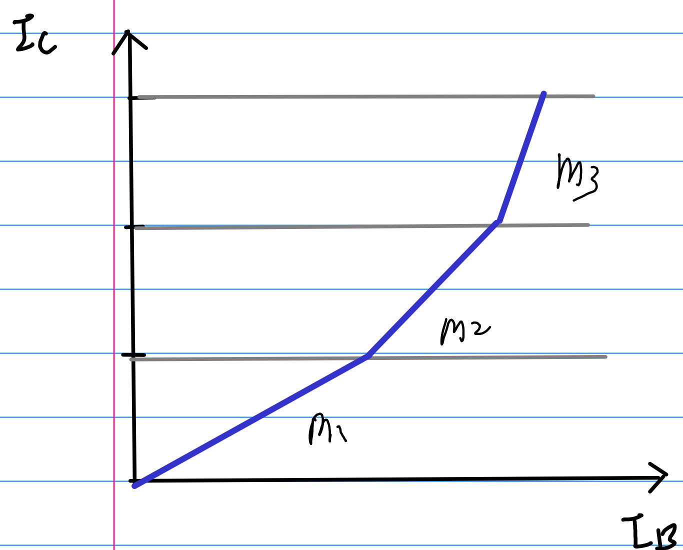


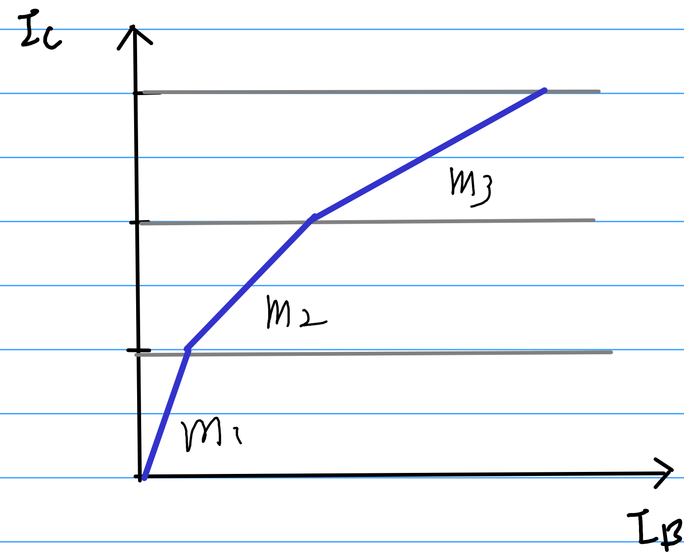
Figure 15. DC Current Gain



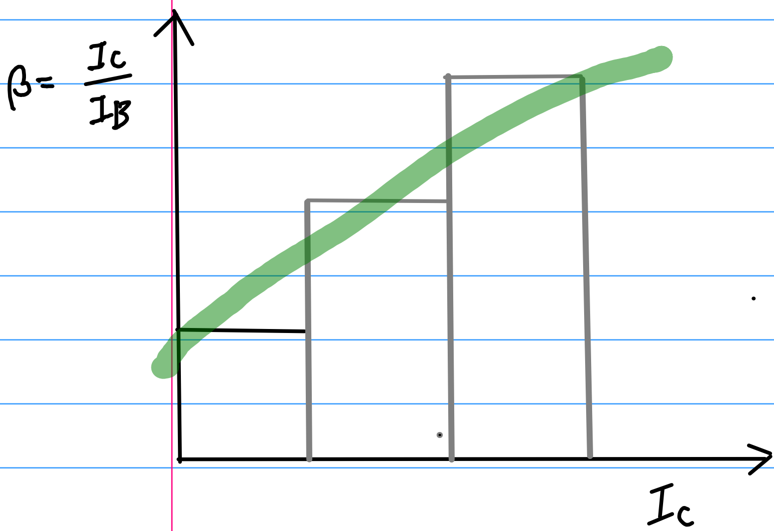


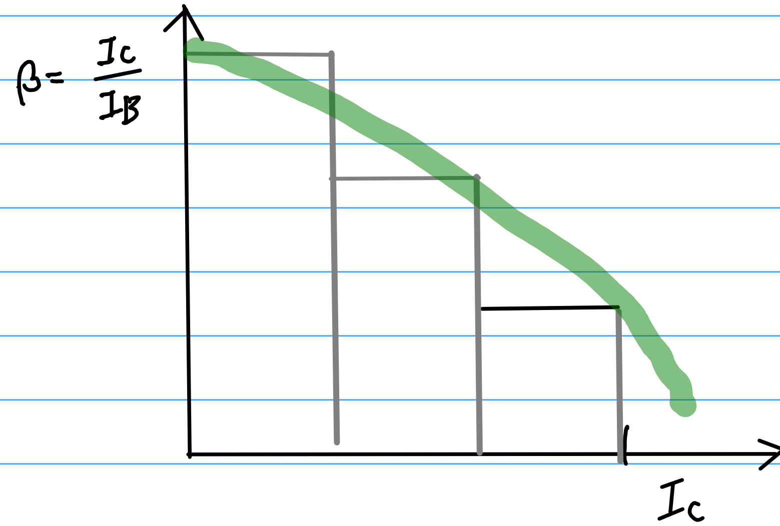


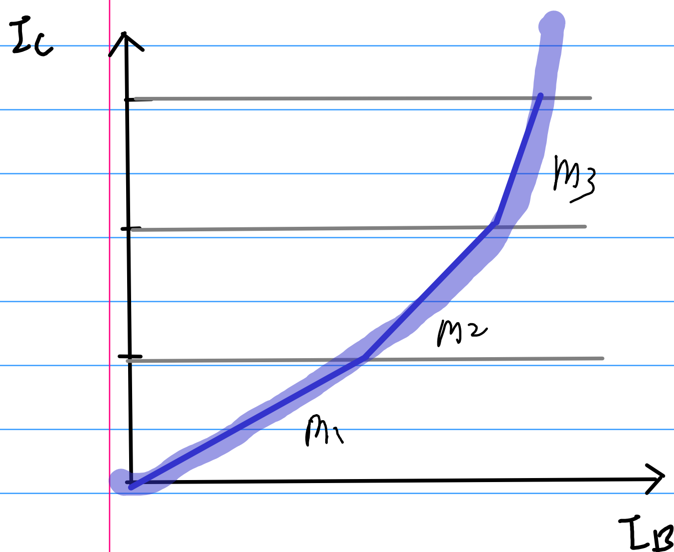
$m_1 < m_2 < m_3$



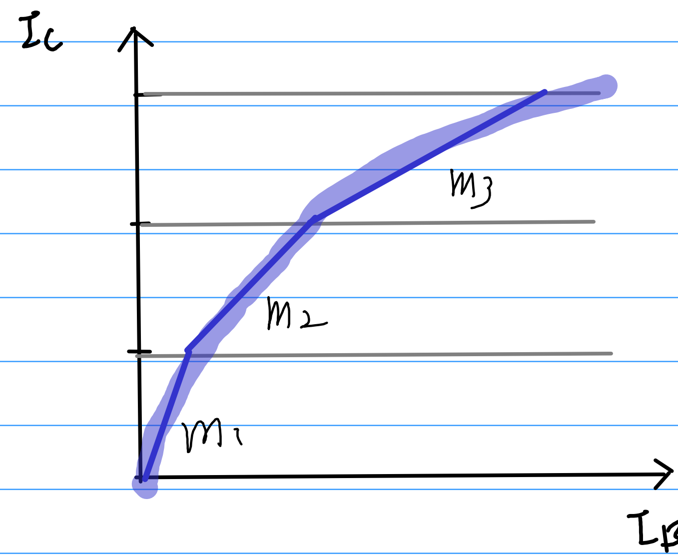
$m_1 > m_2 > m_3$



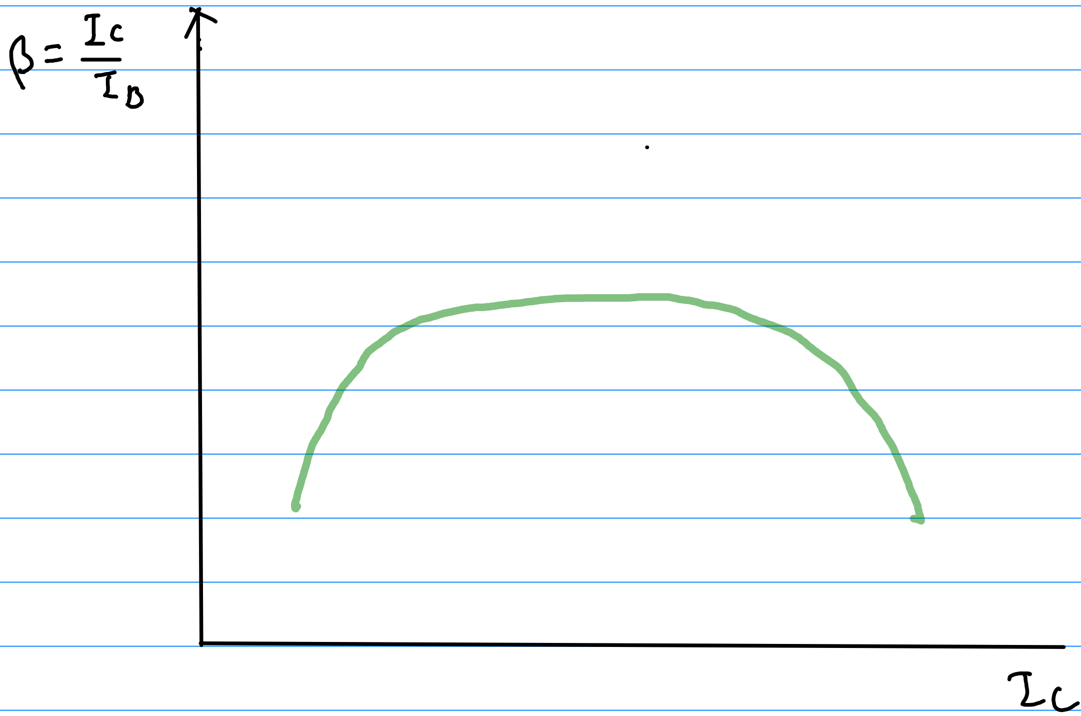




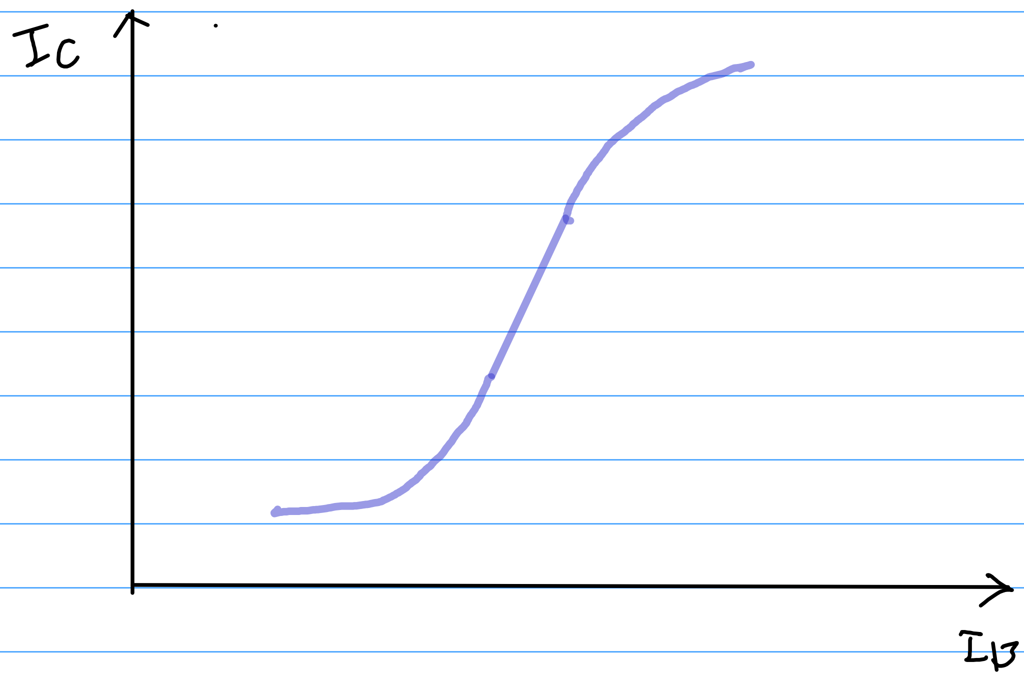
$m_1 < m_2 < m_3$



$m_1 > m_2 > m_3$



$\beta = \frac{I_C}{I_B}$
I_C



I_C
I_B