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# Modelando el Transistor Bipolar

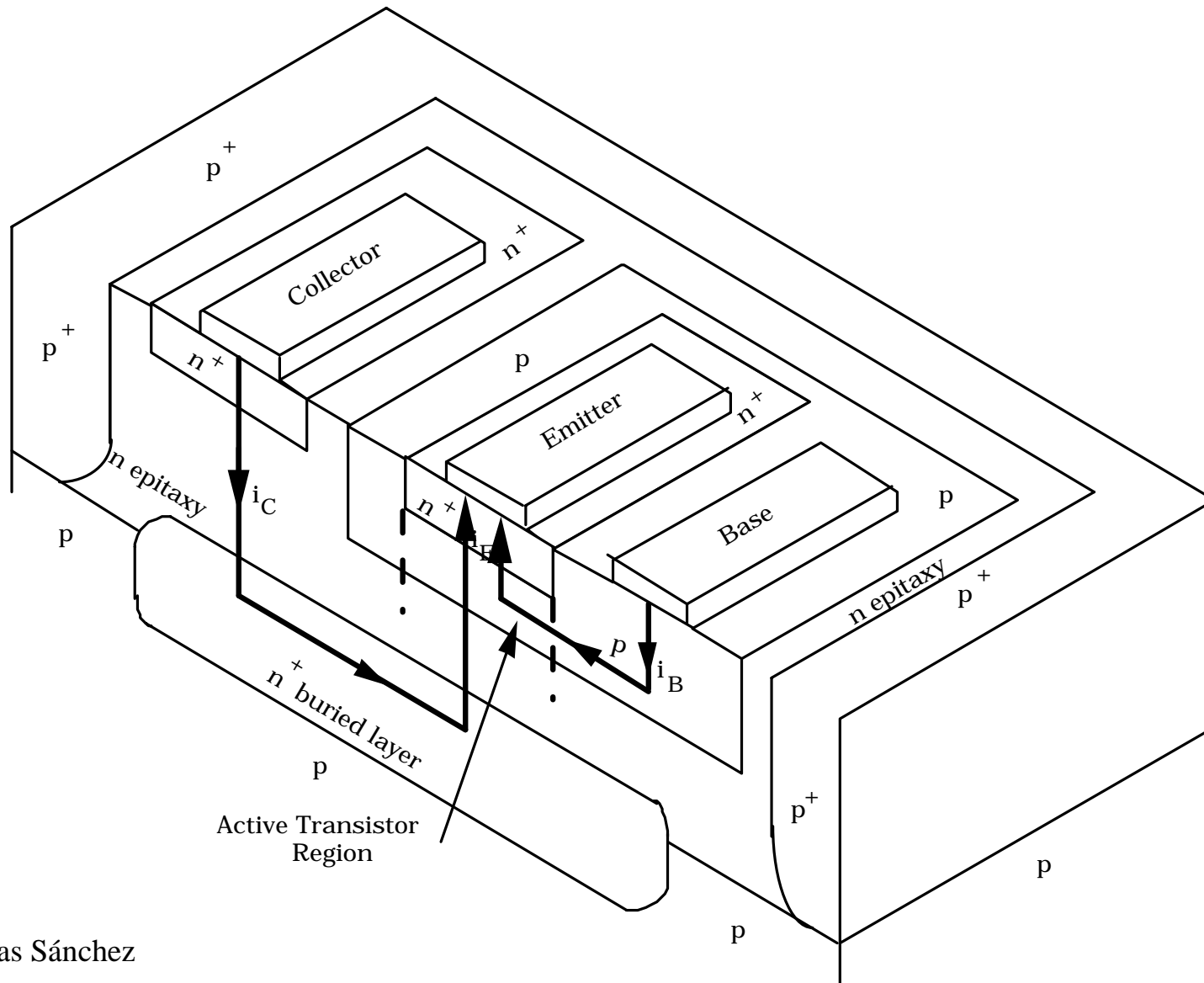
Algunas de las figuras de esta presentación fueron tomadas de las páginas de internet de los autores de los textos:

A.S. Sedra and K.C. Smith, *Microelectronic Circuits*. New York, NY: Oxford University Press, 1998.

A.R. Hambley, *Electronics: A Top-Down Approach to Computer-Aided Circuit Design*. Englewood Cliffs, NJ: Prentice Hall, 2000.

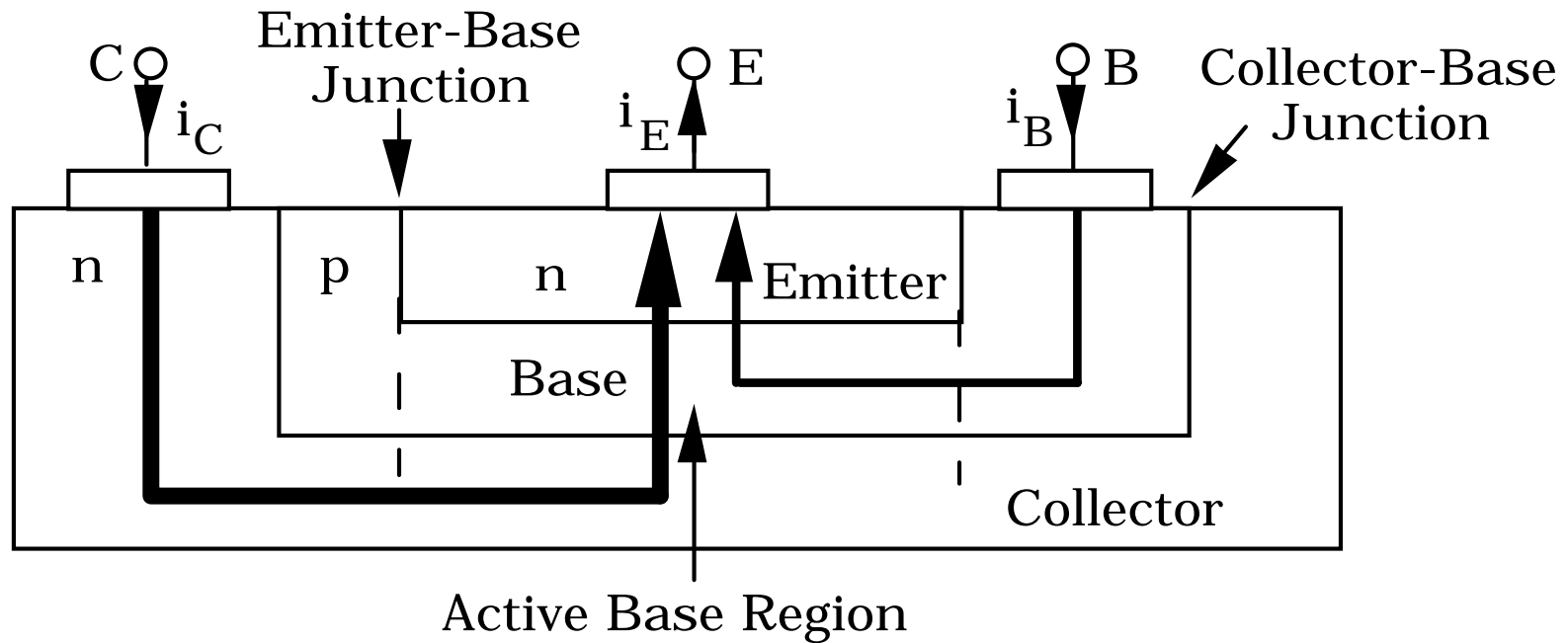
R.C. Jager, *Microelectronic Circuit Design*. New York, NY: McGraw Hill, 1997.

# Estructura del BJT NPN



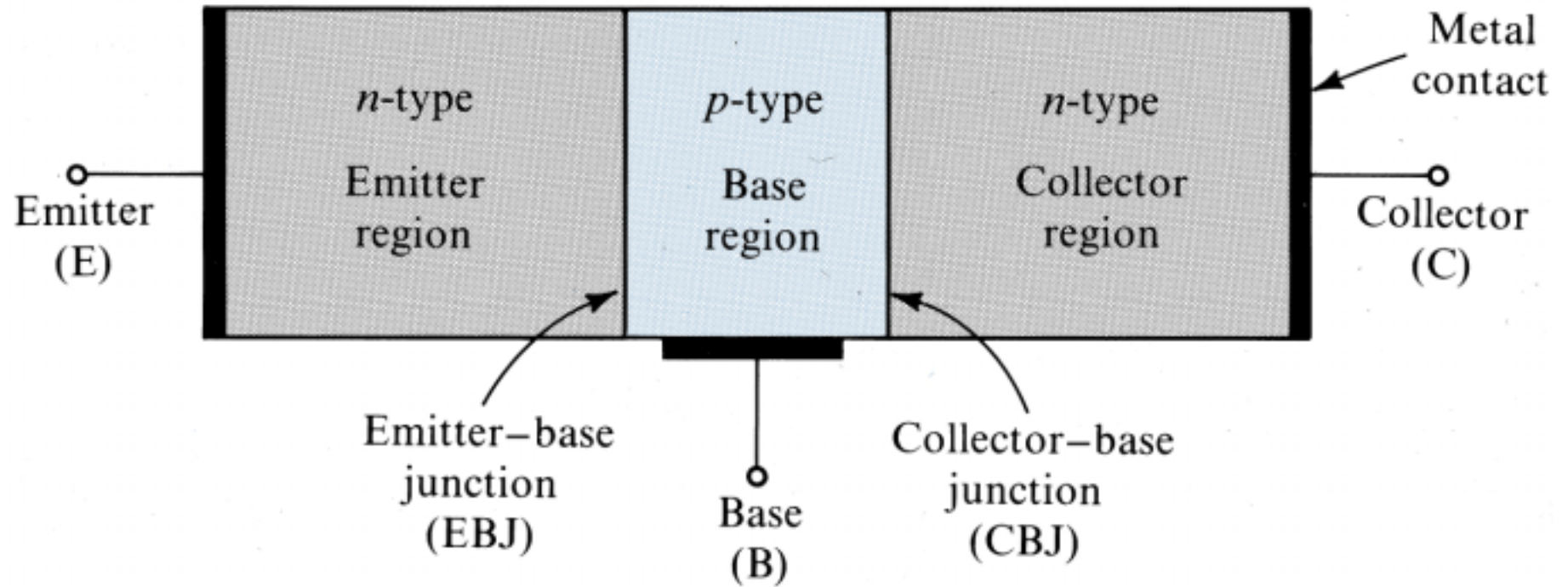
# Sección Transversal de la Estructura del BJT

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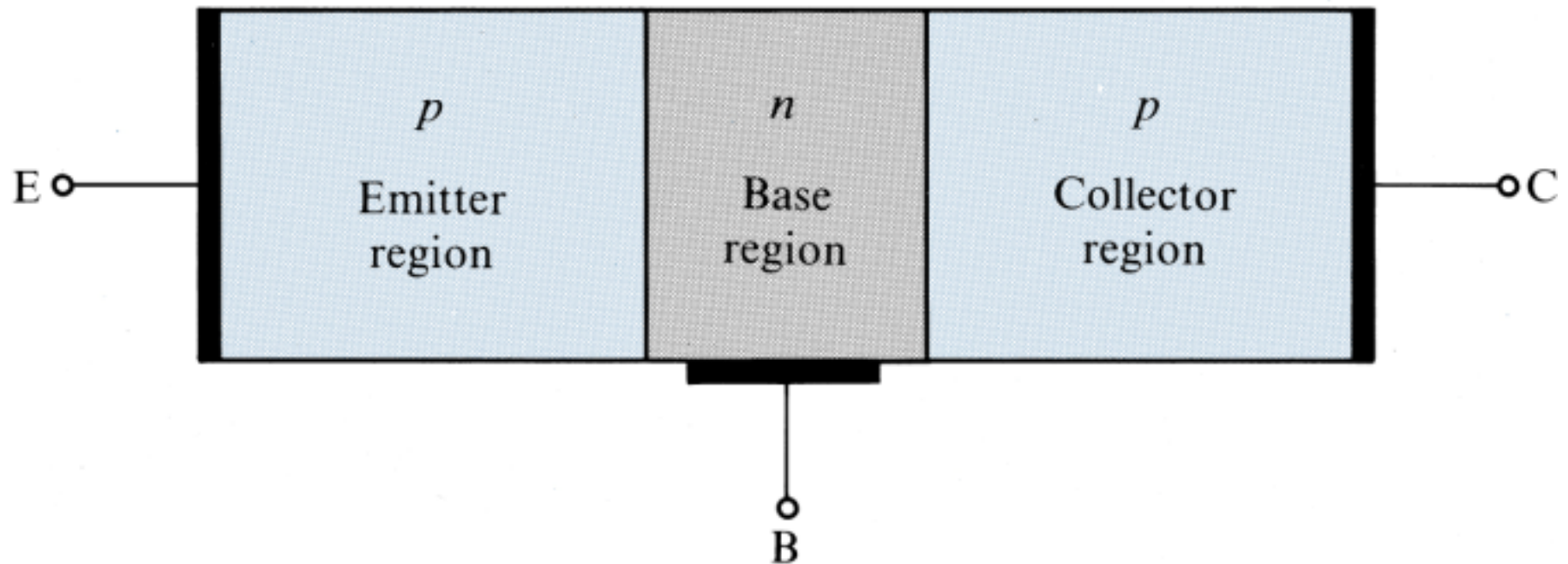
# Estructura Simplificada del BJT NPN

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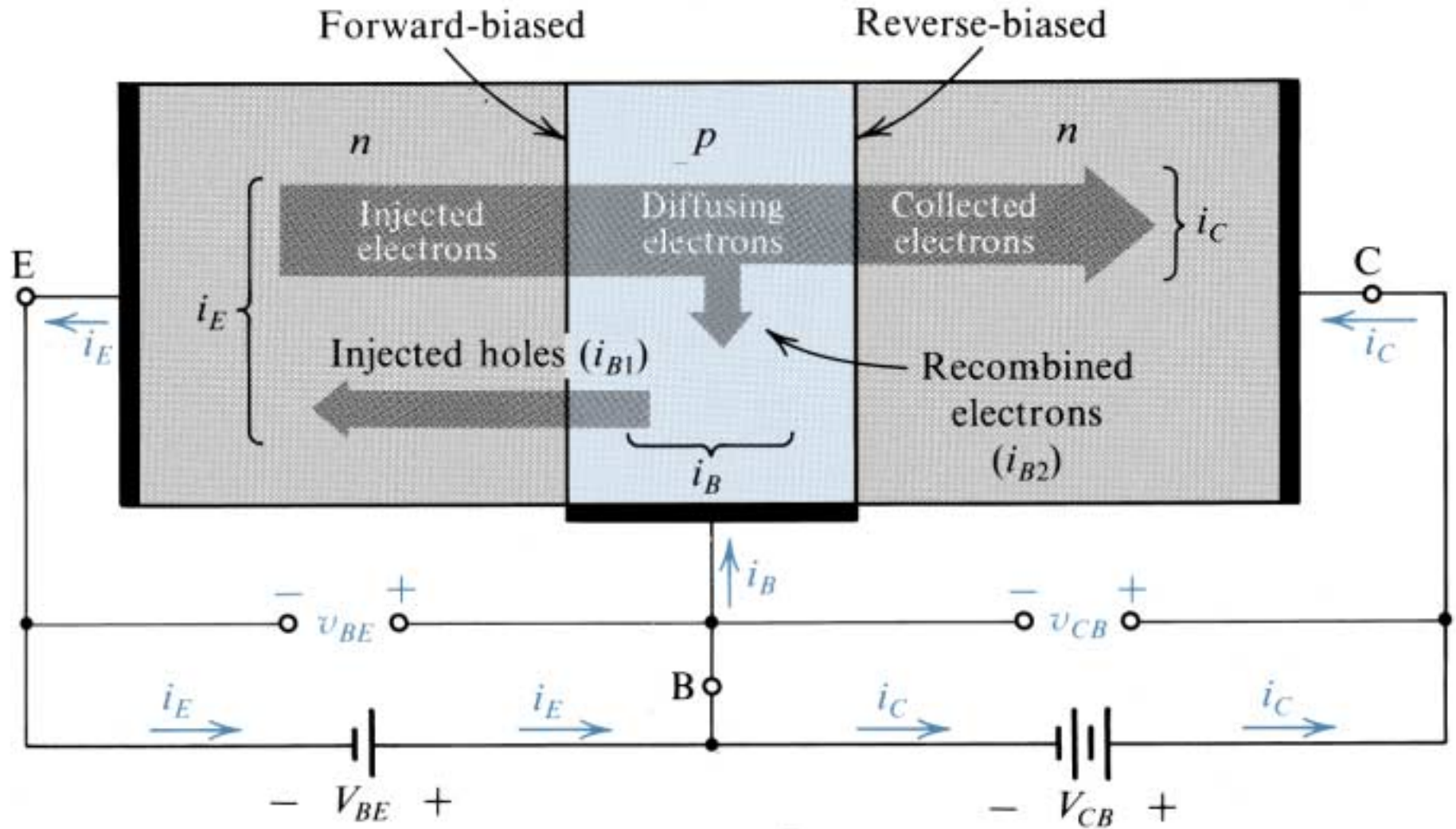


# Estructura Simplificada del BJT PNP

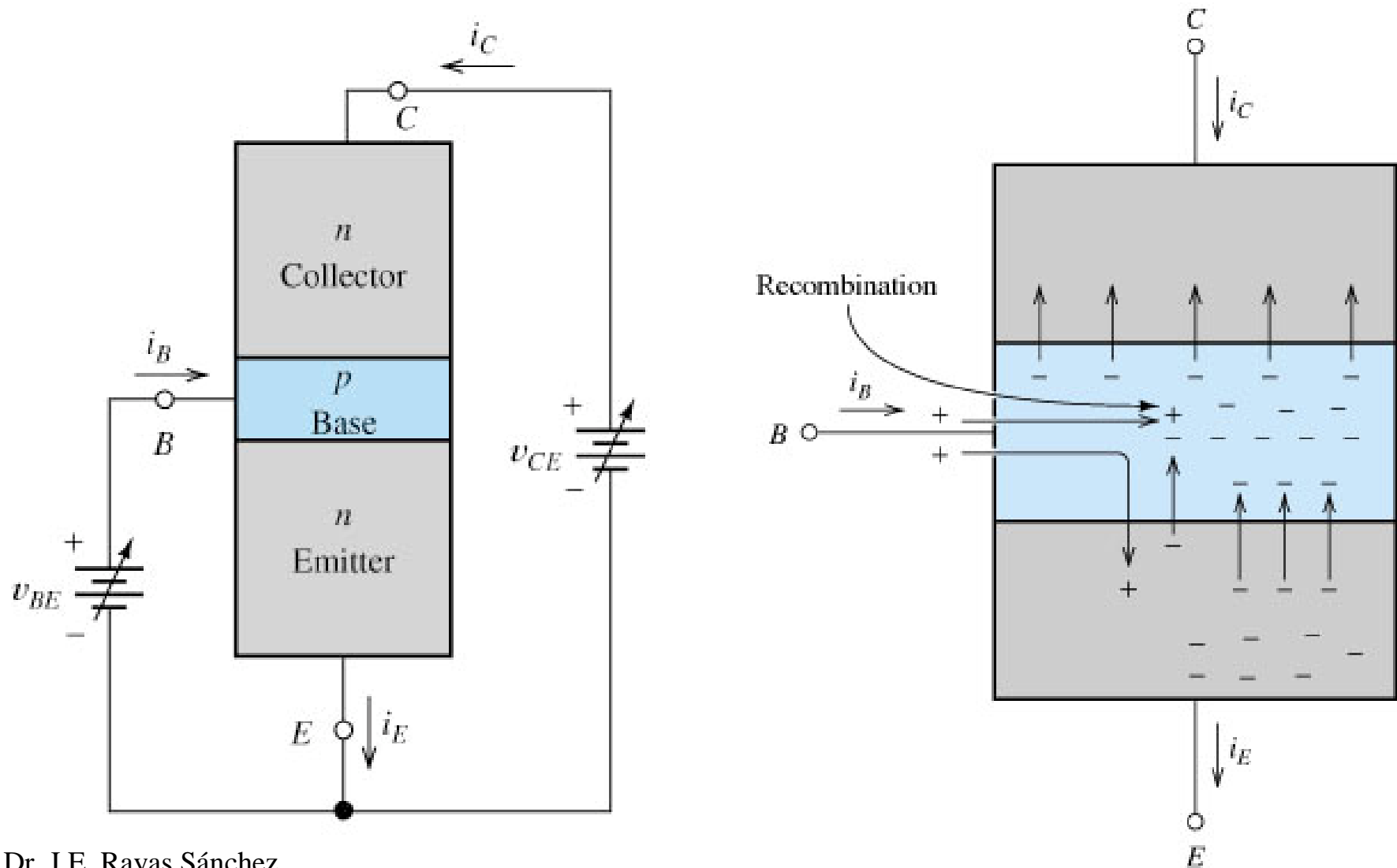
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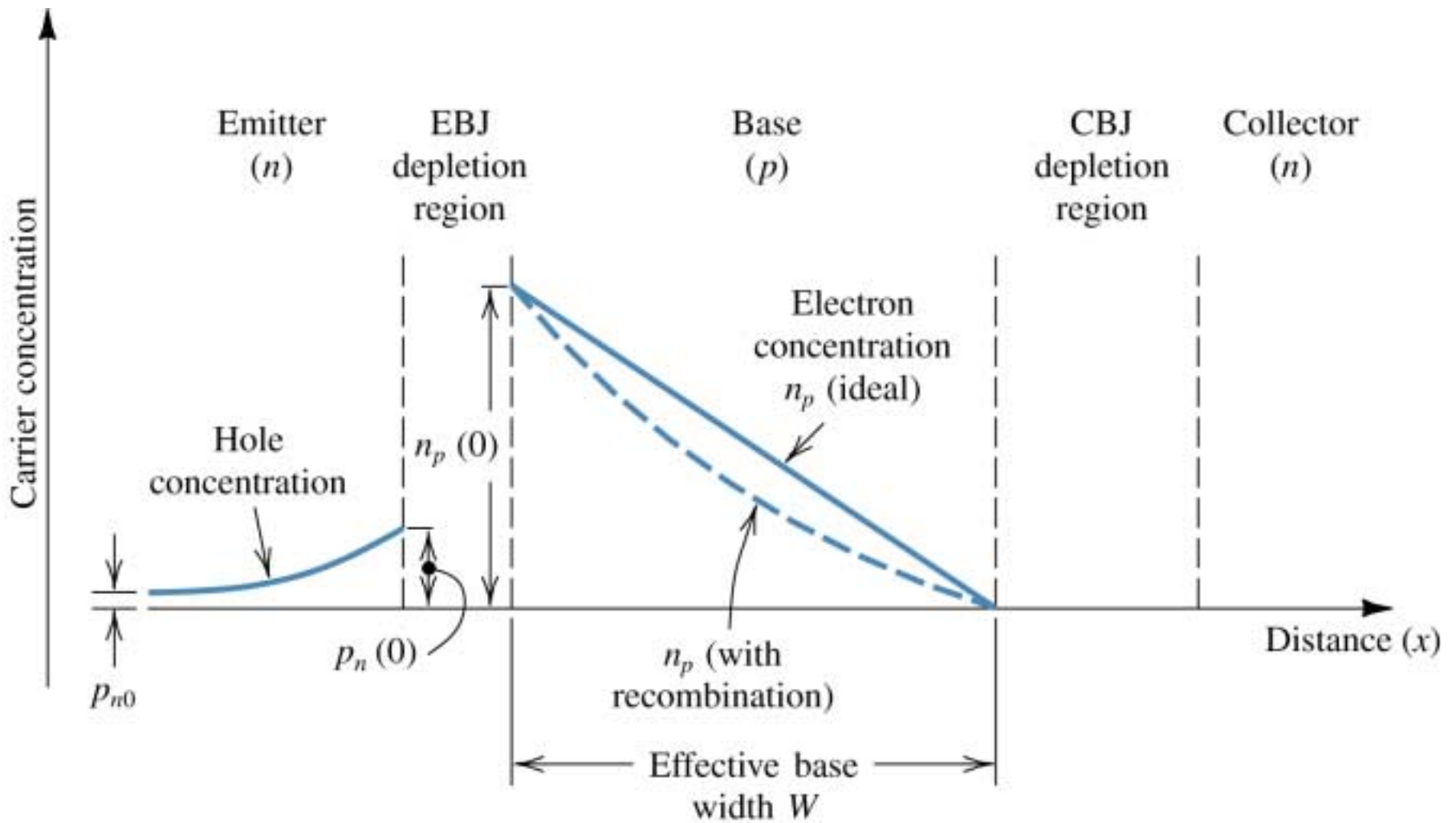
# Operación en la Región Activa



# Operación en la Región Activa (cont.)

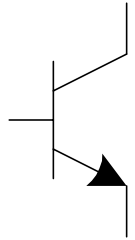


# Portadores Minoritarios en la Base y el Emisor





# Modelos del BJT en Señal Grande

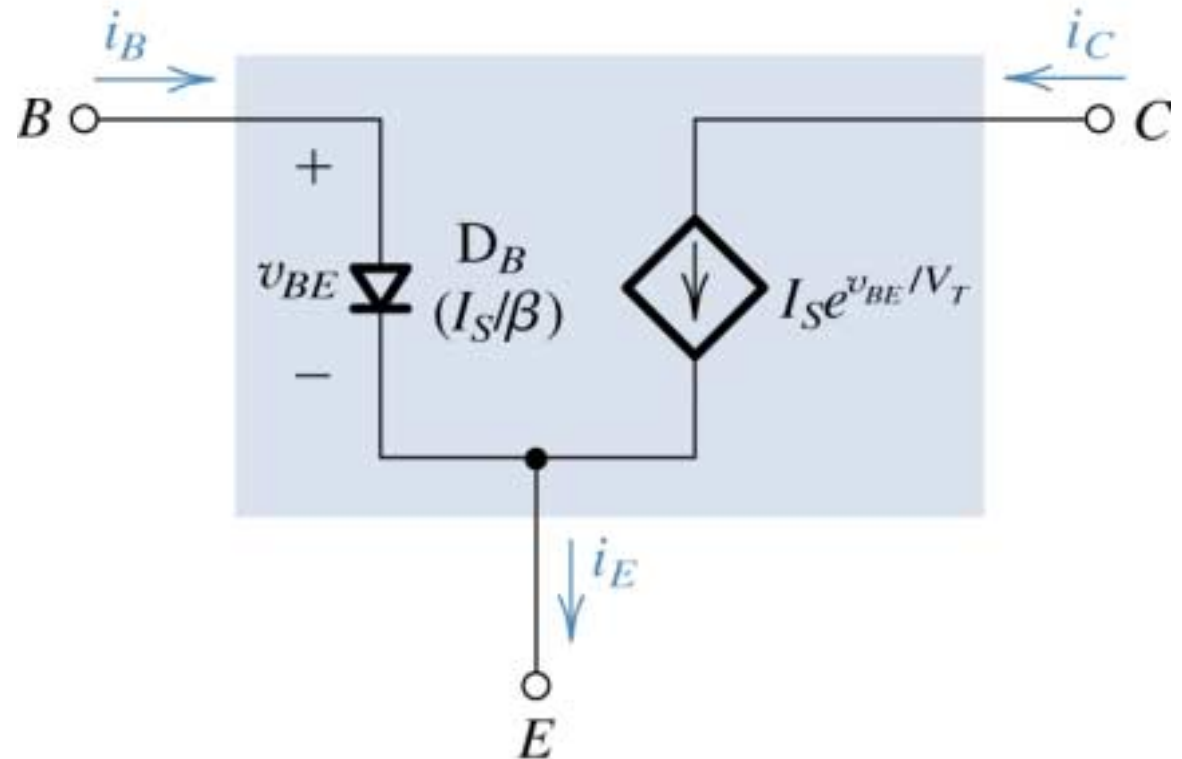


$$i_C = \beta i_B \quad i_E = i_B (1 + \beta) = \frac{i_C}{\beta / (1 + \beta)} = \frac{i_C}{\alpha}$$

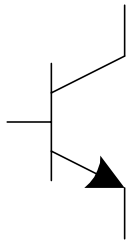
$$i_B = \frac{I_S}{\beta} e^{v_{BE}/V_T}$$

$$i_C = I_S e^{v_{BE}/V_T}$$

$$i_E = \frac{I_S}{\alpha} e^{v_{BE}/V_T}$$



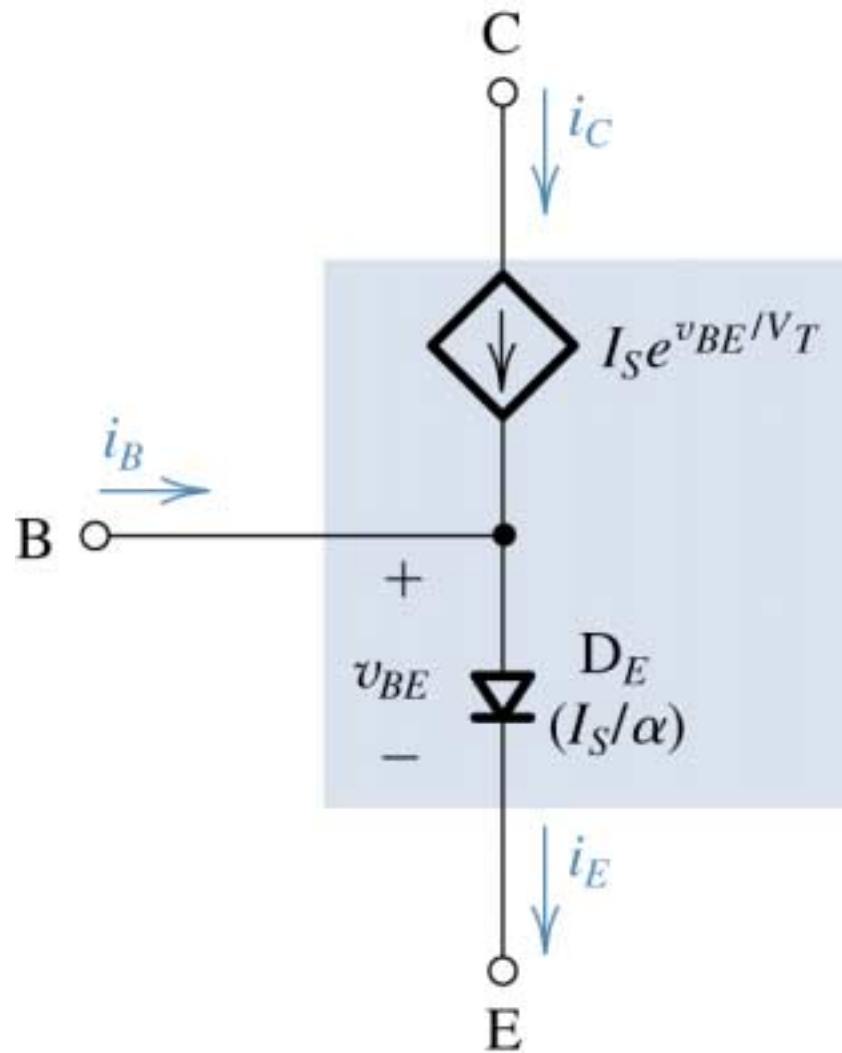
# Modelos del BJT en Señal Grande (cont.)



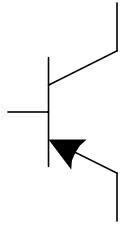
$$i_B = \frac{I_S}{\beta} e^{v_{BE}/V_T}$$

$$i_C = I_S e^{v_{BE}/V_T}$$

$$i_E = \frac{I_S}{\alpha} e^{v_{BE}/V_T}$$



# Modelos del BJT en Señal Grande (cont.)

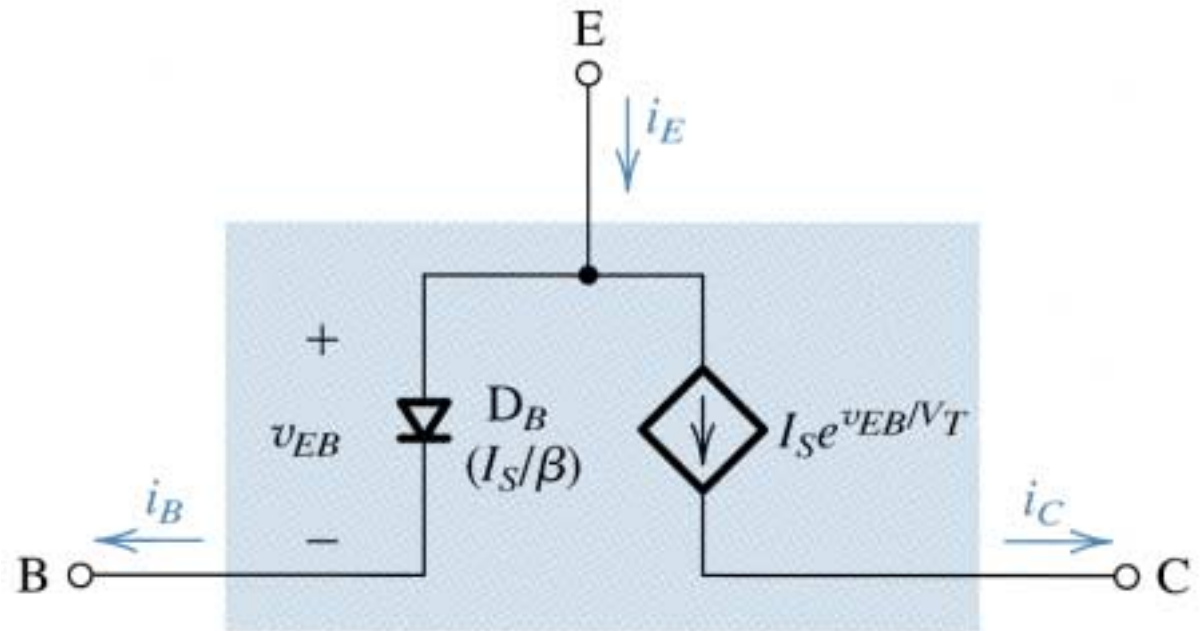


$$i_C = \beta i_B \quad i_E = i_B (1 + \beta) = \frac{i_C}{\beta / (1 + \beta)} = \frac{i_C}{\alpha}$$

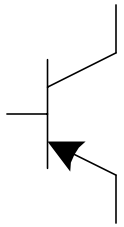
$$i_B = \frac{I_S}{\beta} e^{v_{EB}/V_T}$$

$$i_C = I_S e^{v_{EB}/V_T}$$

$$i_E = \frac{I_S}{\alpha} e^{v_{EB}/V_T}$$



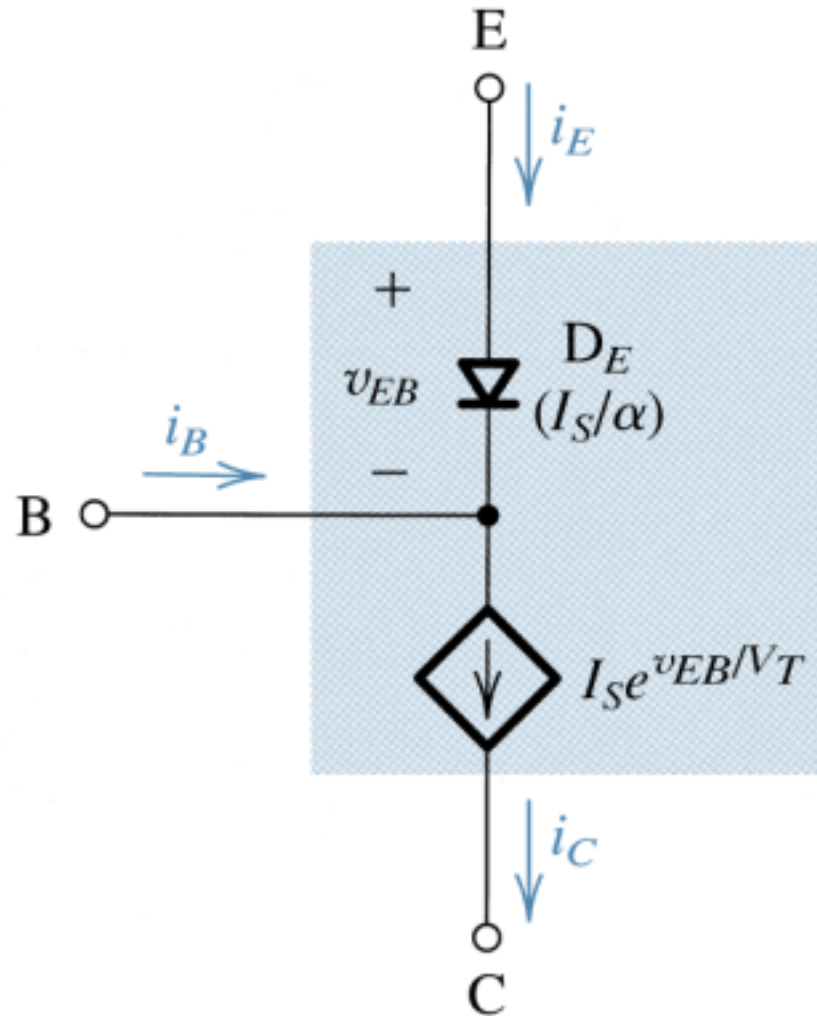
# Modelos del BJT en Señal Grande (cont.)



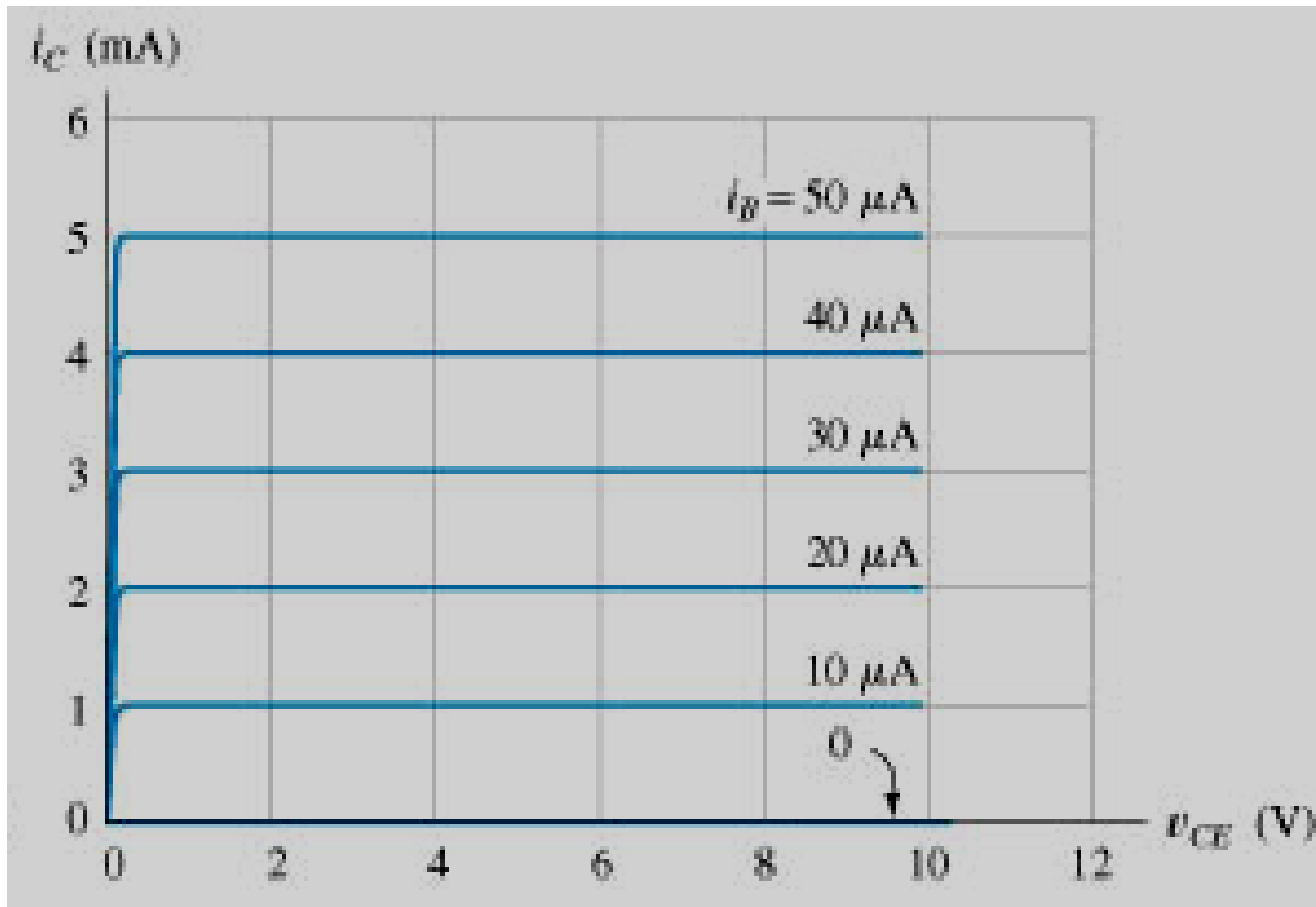
$$i_B = \frac{I_S}{\beta} e^{v_{EB}/V_T}$$

$$i_C = I_S e^{v_{EB}/V_T}$$

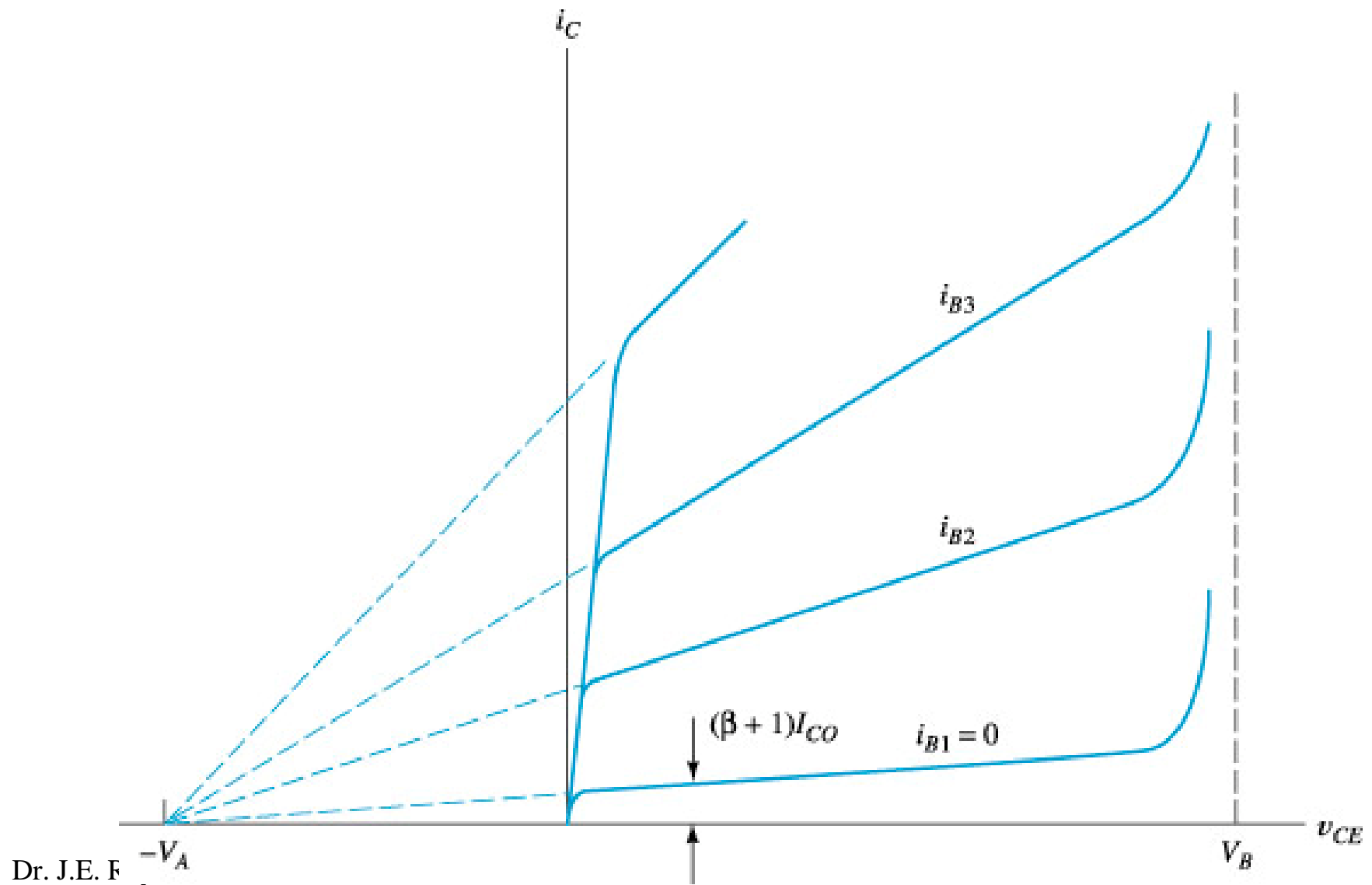
$$i_E = \frac{I_S}{\alpha} e^{v_{EB}/V_T}$$



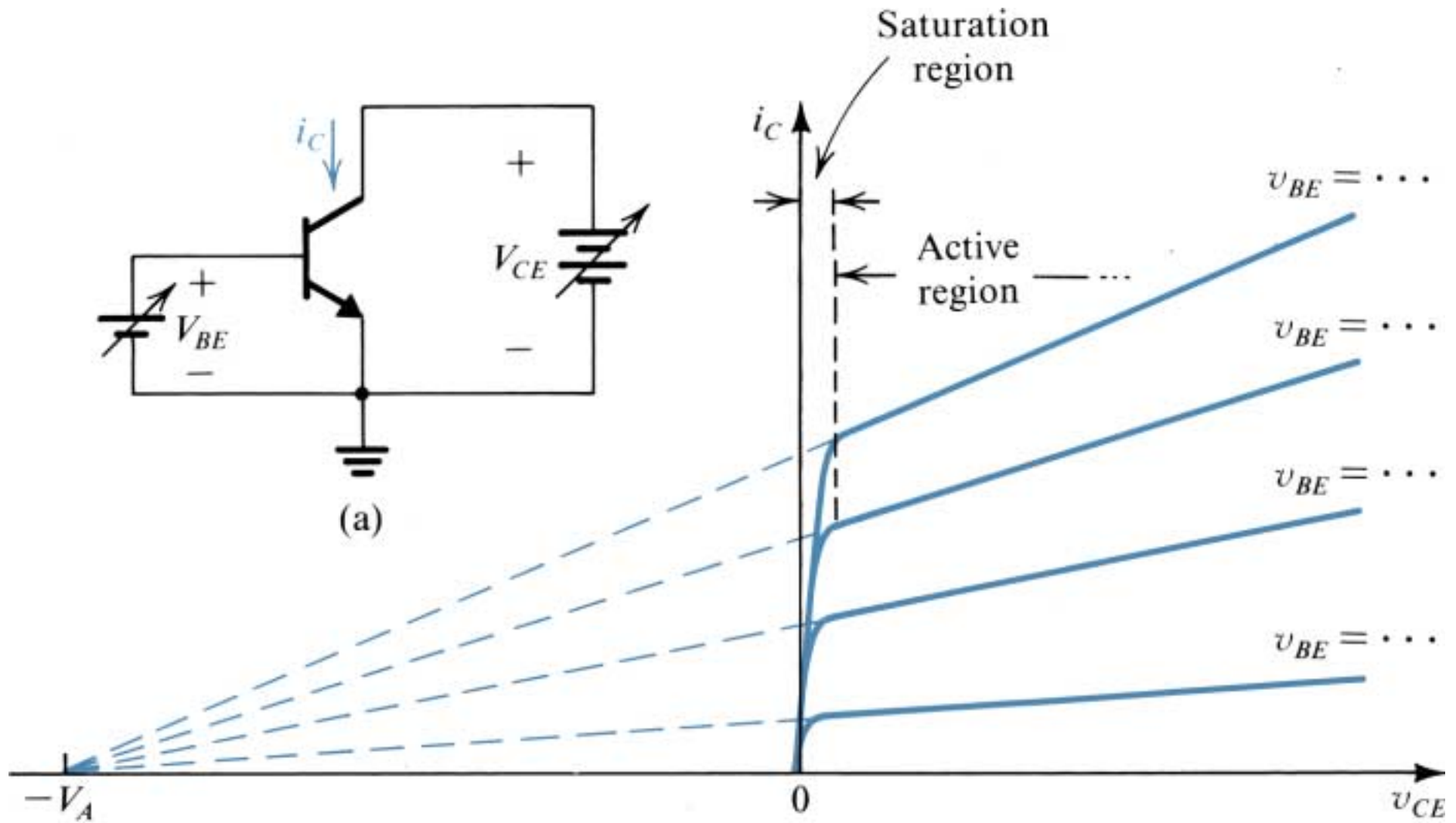
# El BJT como Fuente de Corriente Controlada



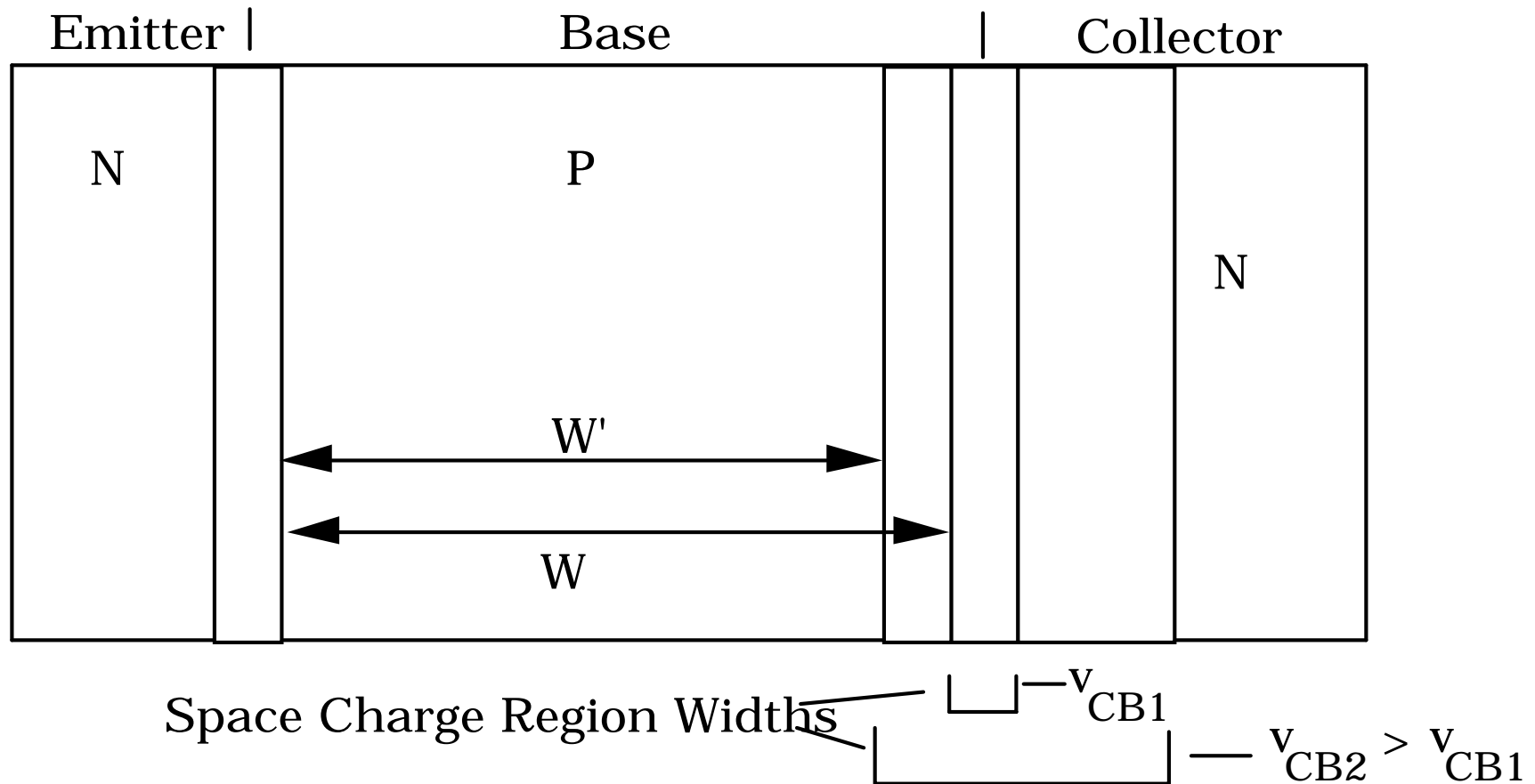
# El BJT como Fuente de Corriente Controlada



# Efecto Early



# Efecto Early (Modulación del Ancho de la Base)





# Modelando el Efecto Early

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NPN

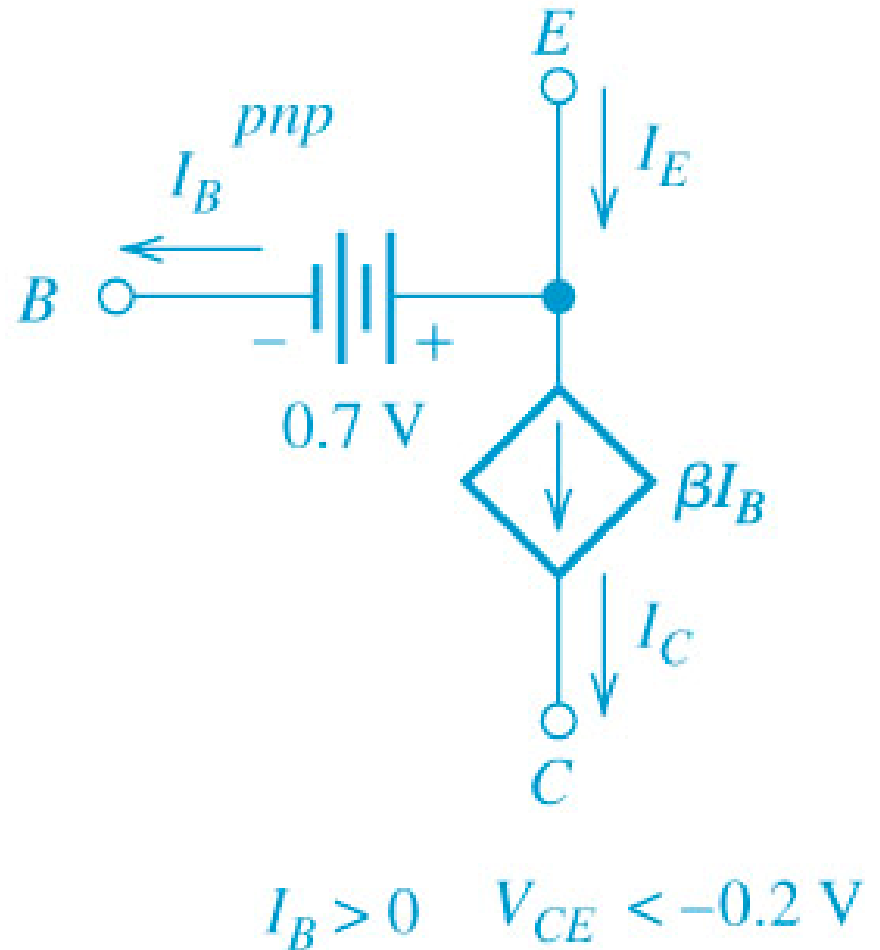
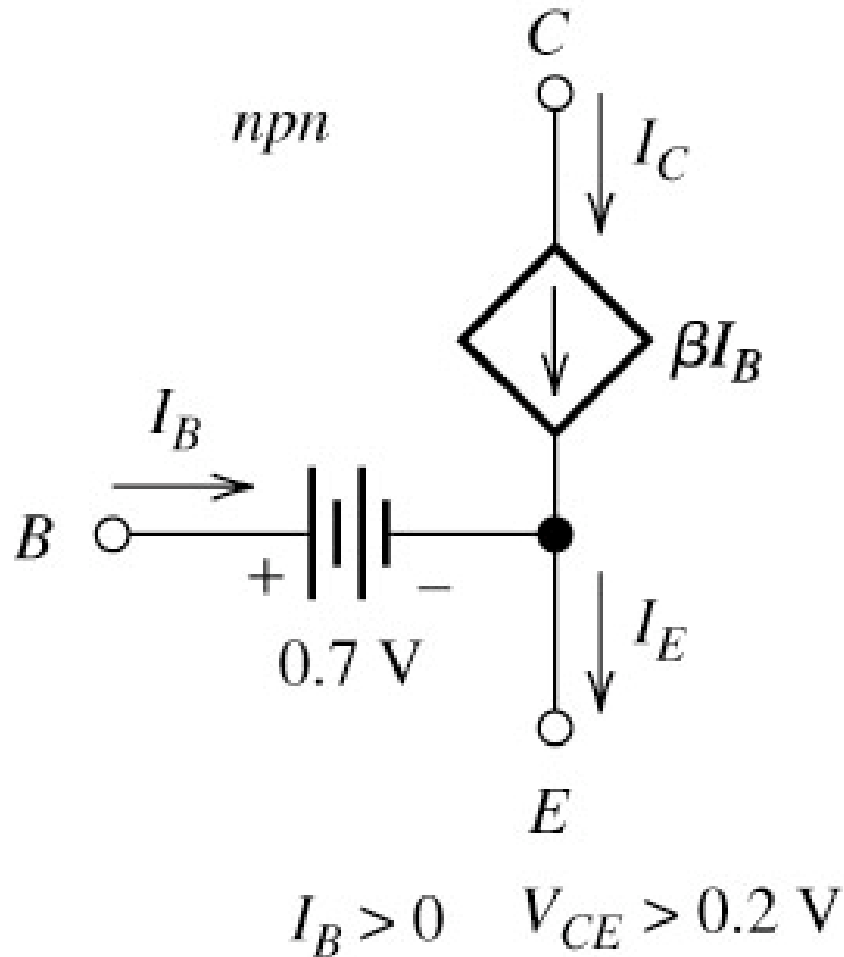
$$i_C = I_S \left(1 + \frac{V_{CE}}{V_A}\right) e^{v_{BE}/V_T}$$

PNP

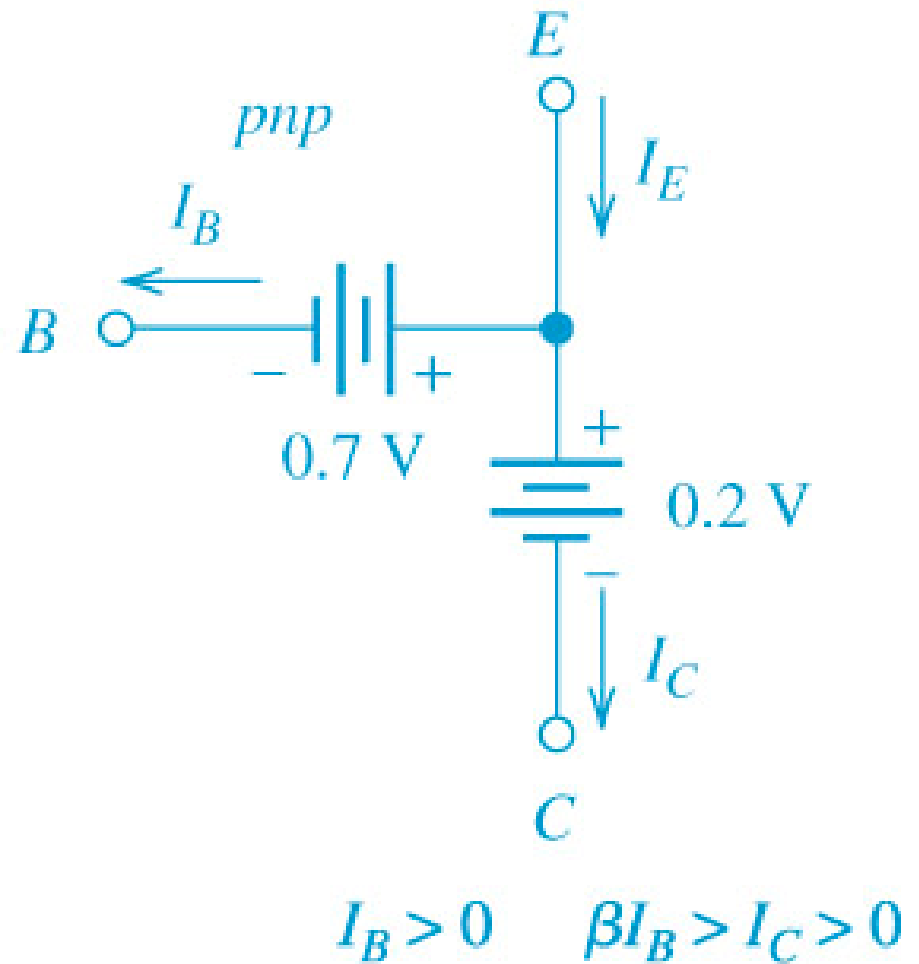
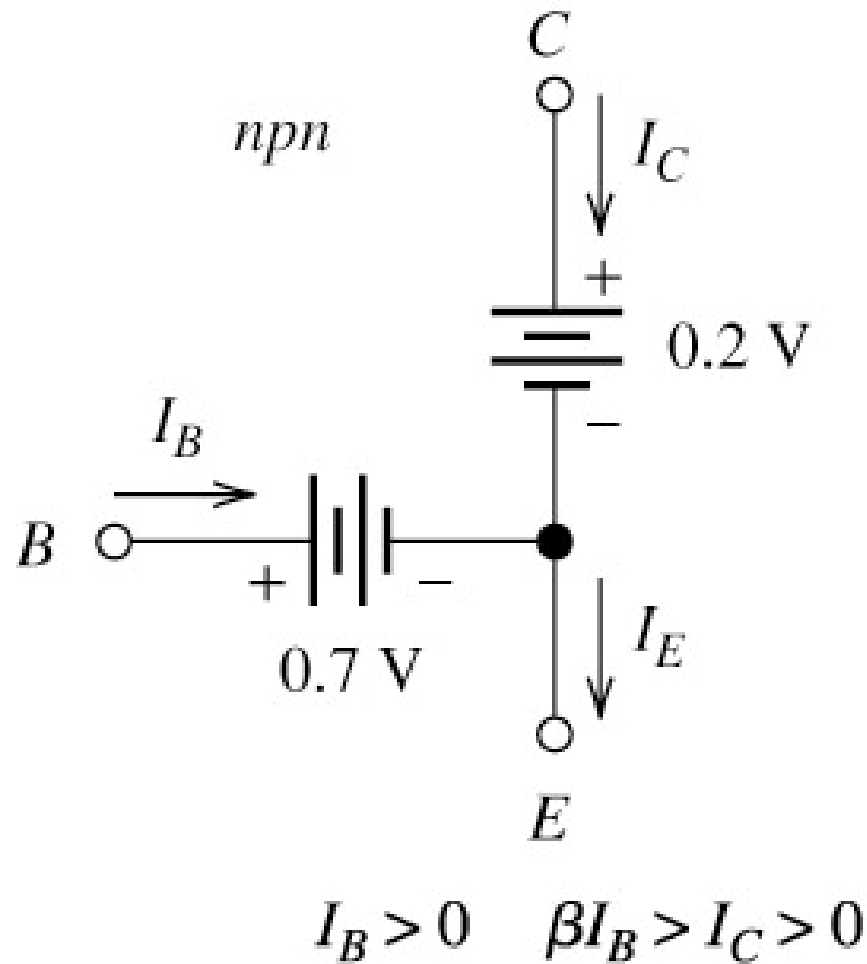
$$i_C = I_S \left(1 + \frac{V_{EC}}{V_A}\right) e^{v_{EB}/V_T}$$

$V_A$  Voltaje Early

# Modelos Simplificados para la Región Activa

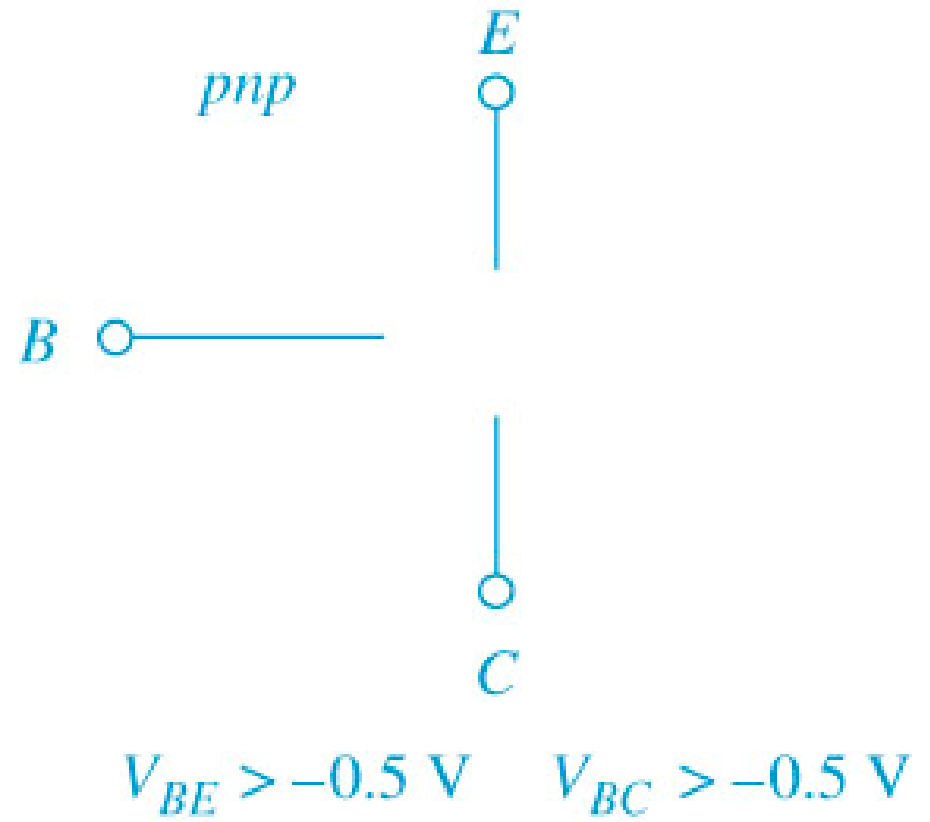
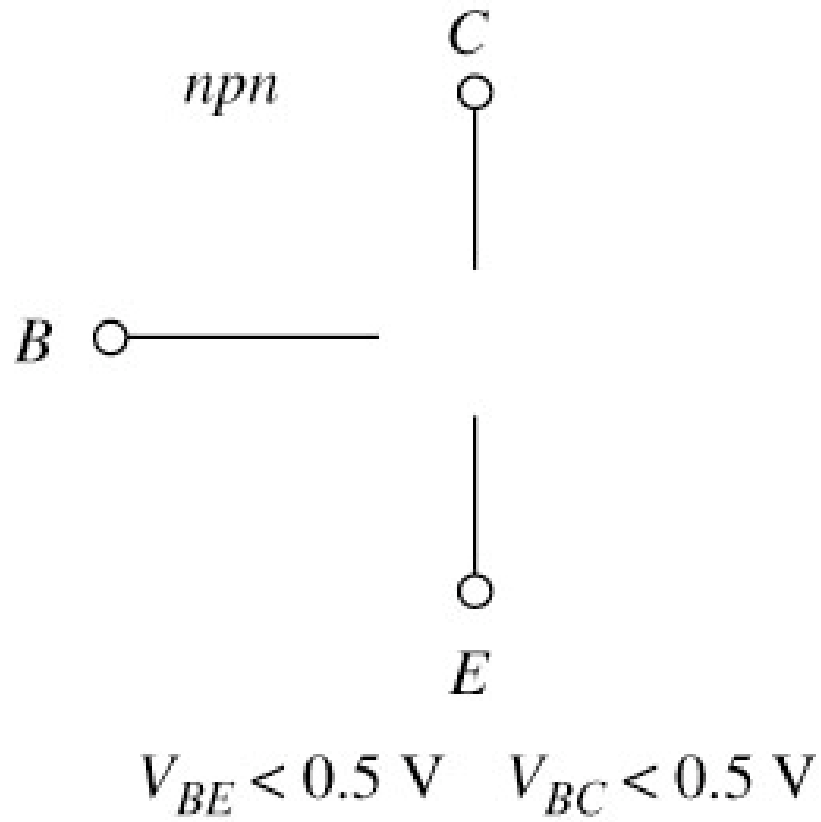


# Modelos Simplificados para Saturación



# Modelos Simplificados para Corte

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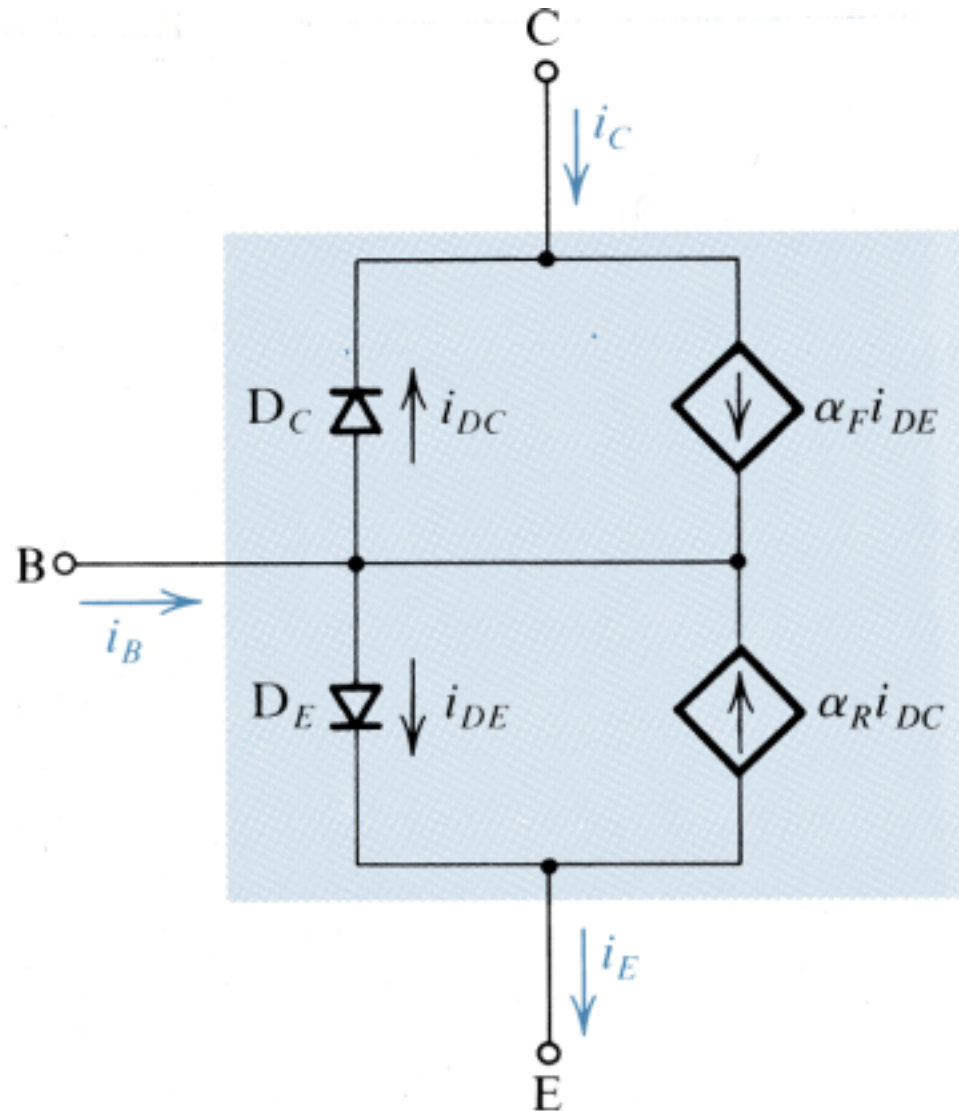
# Regiones de Operación del BJT

TABLE 5.2 - Regions of Operation of the Bipolar Transistor		
Base-Emitter Junction	Base-Collector Junction	
	Forward Bias	Reverse Bias
Forward Bias	<b>Saturation Region</b> (Closed Switch)	<b>Forward-Active Region</b> (Normal-Active Region) (Good Amplifier)
Reverse Bias	<b>Reverse-Active Region</b> (Inverse-Active Region) (Poor Amplifier)	<b>Cutoff Region</b> (Open Switch)

# Modelo de Ebers-Moll

$$i_{DE} = I_{SE} (e^{v_{BE}/V_T} - 1)$$

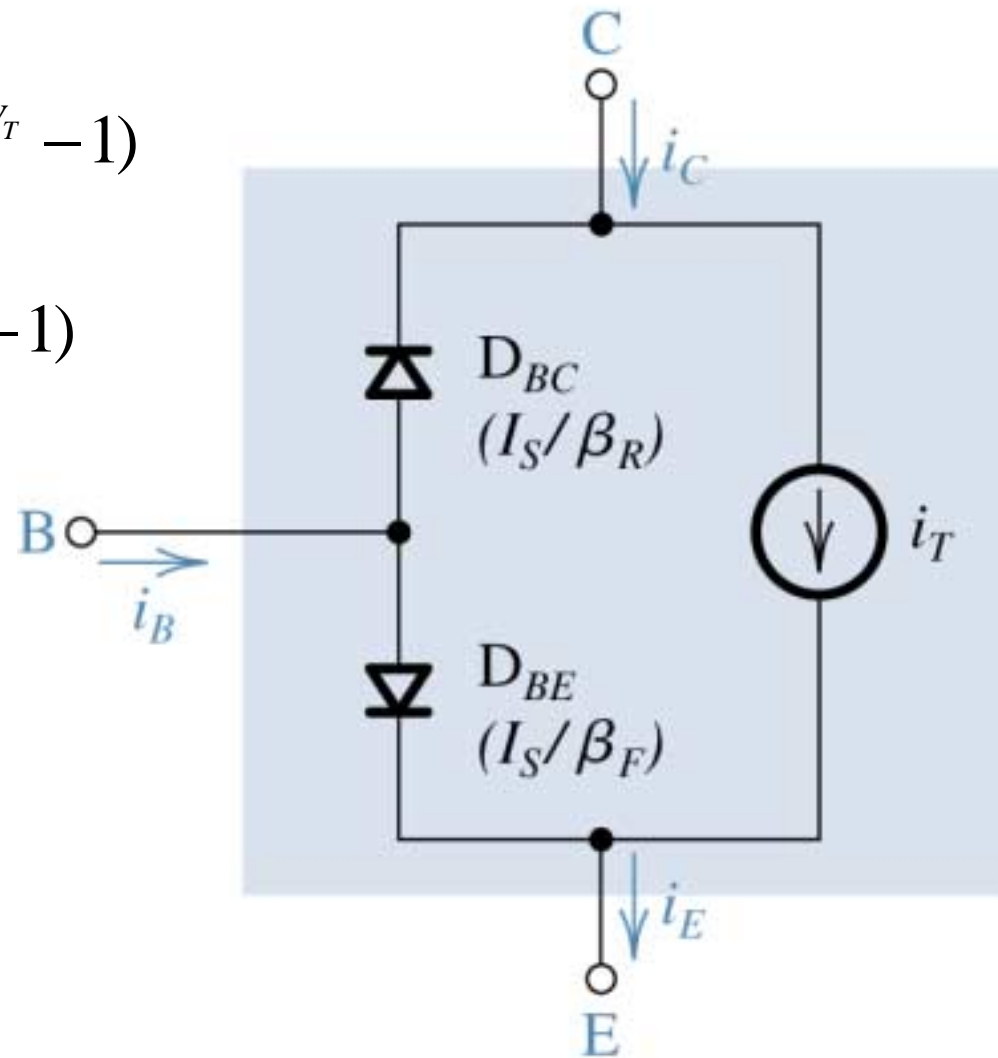
$$i_{DC} = I_{SC} (e^{v_{BC}/V_T} - 1)$$



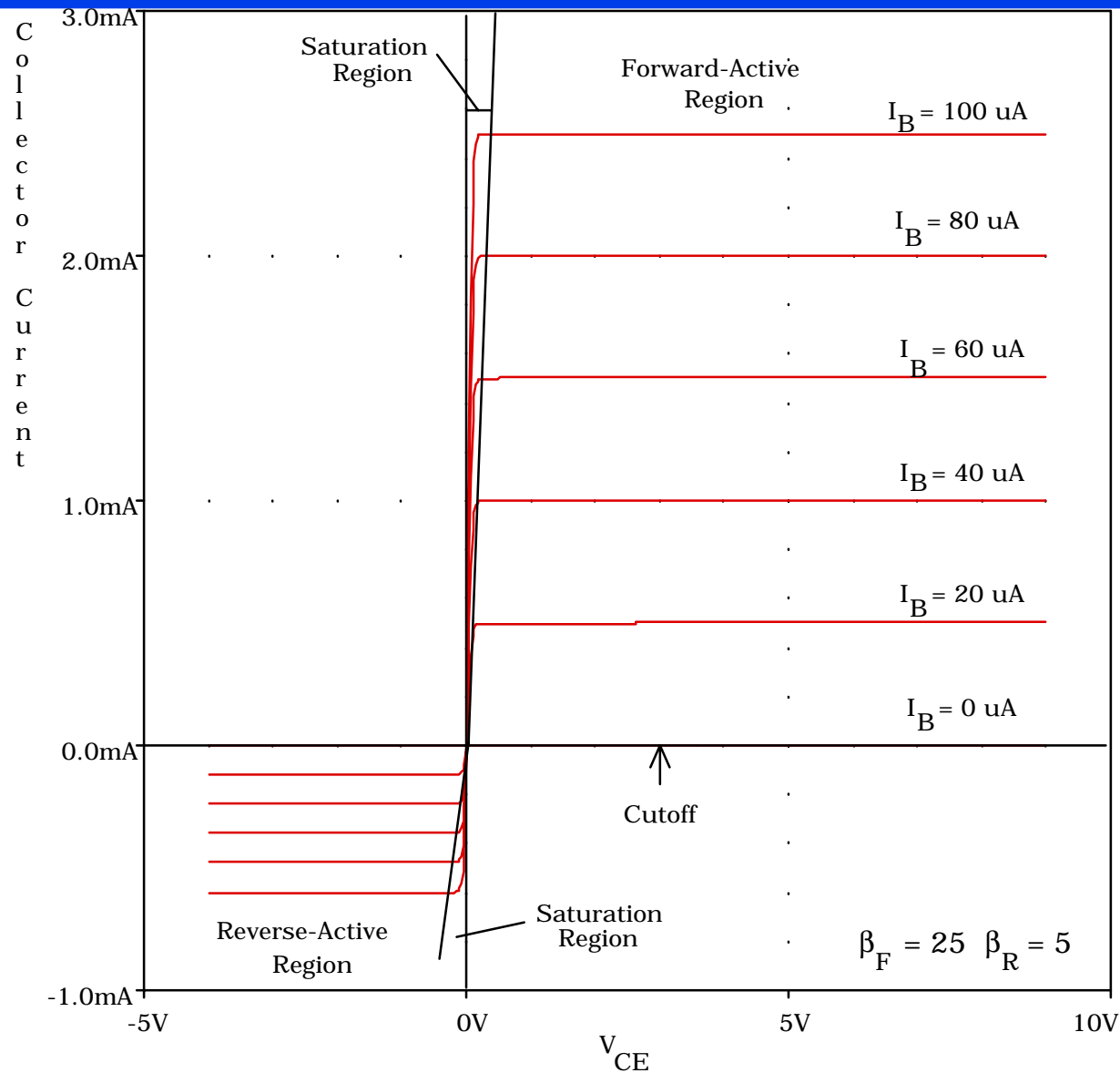
# Modelo de Transporte

$$i_B = \frac{I_S}{\beta_F} (e^{v_{BE}/V_T} - 1) + \frac{I_S}{\beta_R} (e^{v_{BC}/V_T} - 1)$$

$$i_T = I_S (e^{v_{BE}/V_T} - 1) + I_S (e^{v_{BC}/V_T} - 1)$$

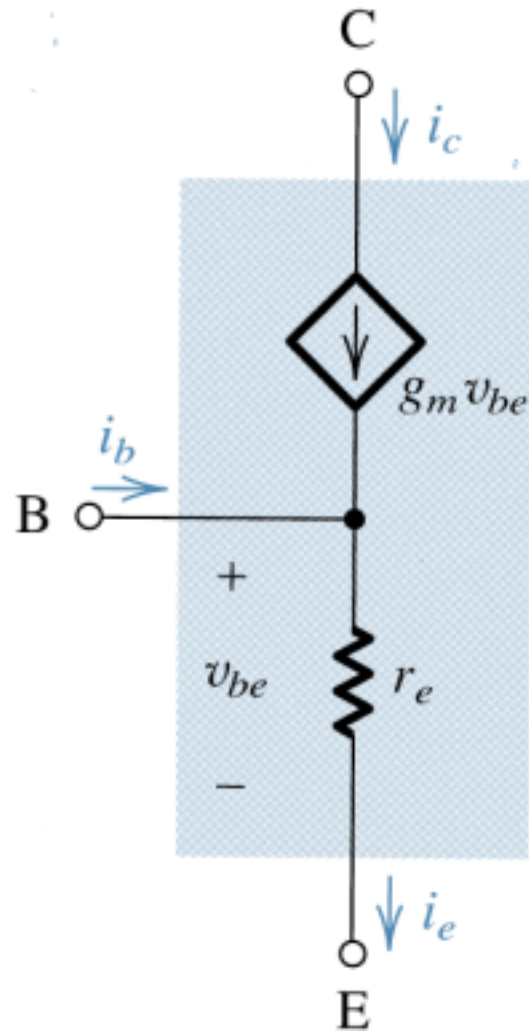


# Región Activa VS Región Inversa



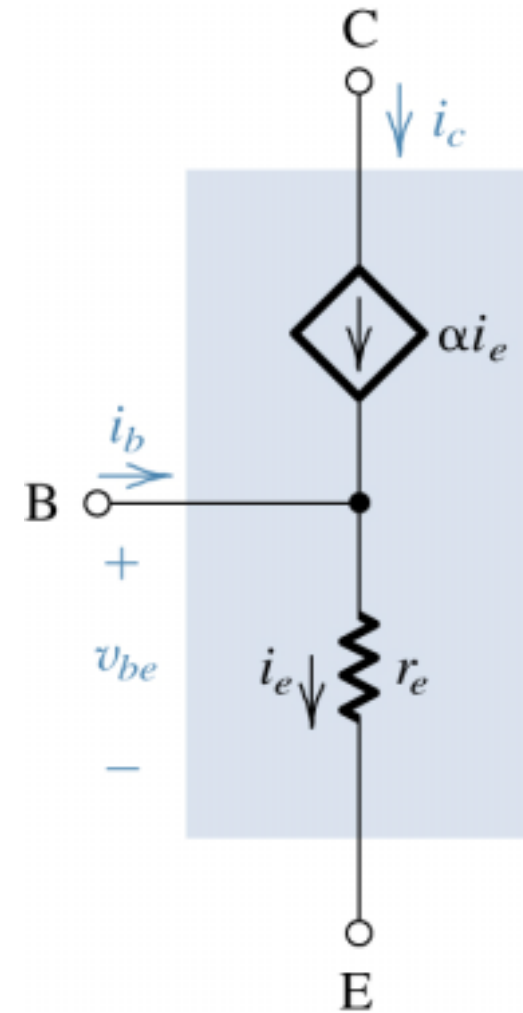


# Modelos del BJT para Señal Pequeña



$$g_m = I_C / V_T$$

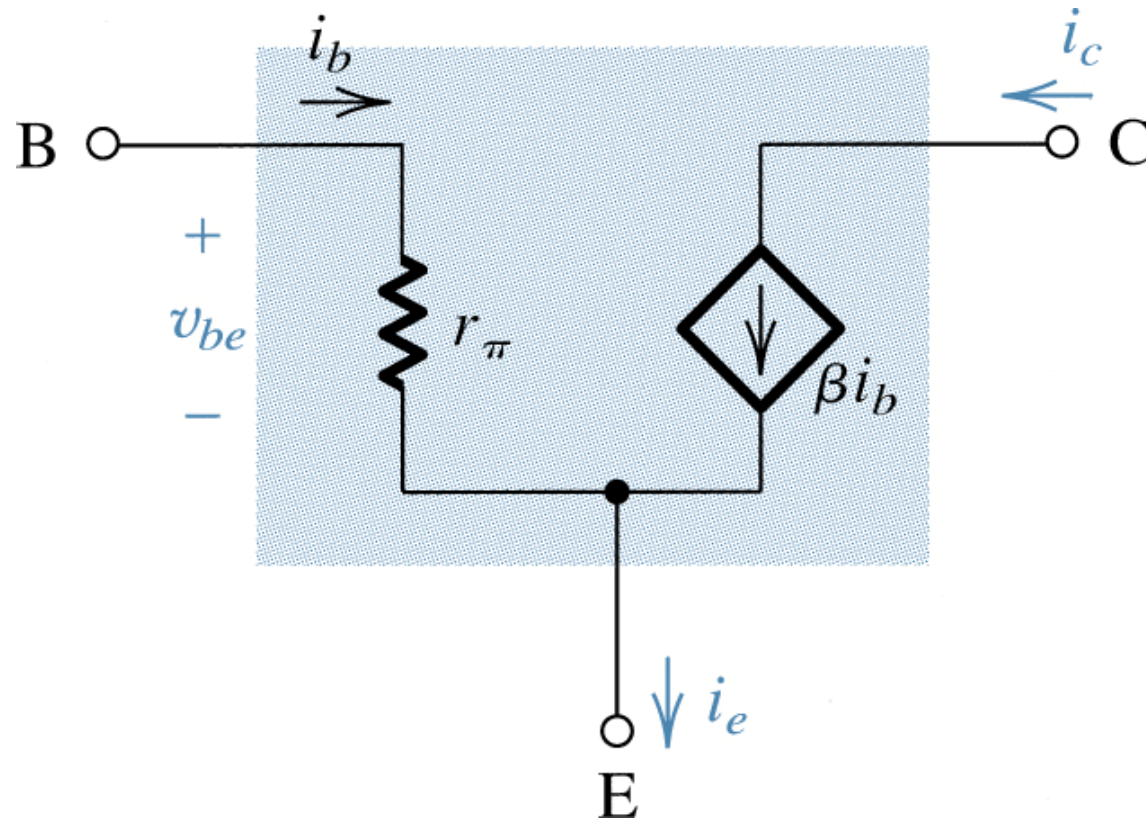
$$r_e = \frac{V_T}{I_E} = \frac{\alpha}{g_m}$$



# Modelos del BJT para Señal Pequeña (cont.)

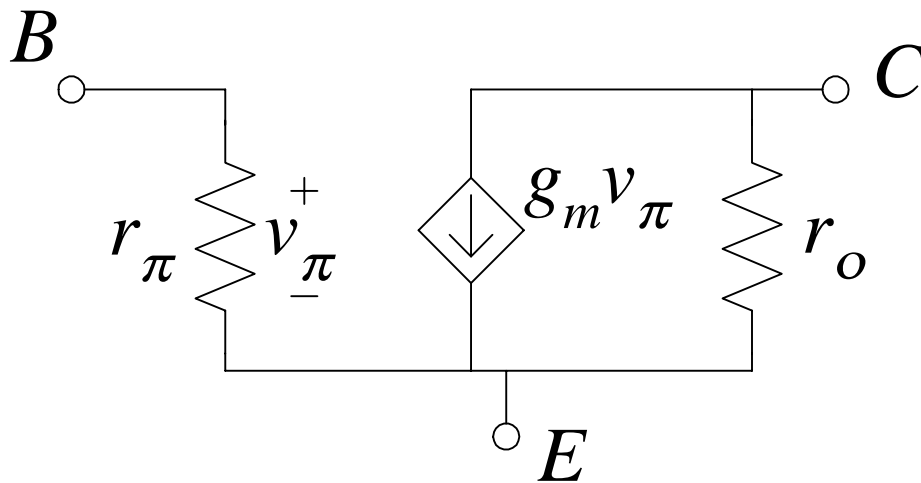
$$r_{\pi} = \frac{\beta}{g_m}$$

$$g_m = \frac{I_C}{V_T}$$



# Modelos del BJT para Señal Pequeña (cont.)

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$$g_m = \frac{I_C}{V_T}$$

$$r_\pi = \frac{\beta}{g_m}$$

$$r_o = \frac{V_A}{I_C}$$

$V_A$ : Voltaje Early

# Modelos del BJT para Señal Pequeña (cont.)

