$$I_E = I_B + (\alpha I_E + I_{CBO})$$

$$\therefore \quad I_B = I_E - (\alpha I_E + I_{CBO})$$

$$\therefore \quad I_B = (1-\alpha) I_E - I_{CBO} \qquad \ldots (5.8)$$

$\therefore$

Neglecting I_{CBO} we can write,

$$I_B = (1-\alpha) I_E \qquad \ldots (5.9)$$

Ex. 5.2 : *In a certain transistor, 99.6 % of the carriers injected into the base cross the collector-base junction. If the leakage current is 5 μA and the collector current is 20mA, calculate (i) the value of α (ii) the emitter current.*

Sol. : Given : $I_C = 0.996 I_E$, $I_{CBO} = 5\,\mu A$, $I_C = 20$ mA

i) $$\alpha = \frac{I_C}{I_E} = 0.996$$

$$I_C = \alpha I_E + I_{CBO}$$

ii) $$\therefore \quad I_E = \frac{I_C - I_{CBO}}{\alpha} = \frac{20\text{ mA} - 5\,\mu\text{A}}{0.996}$$

$$= 20.07\text{ mA}$$

Ex. 5.3 : *Calculate the values of collector current and base current for a transistor with α and I_{CBO} = 10 μA. The emitter current is measured as 8 mA.*

Sol. : Given : $\alpha = 0.99$, $I_{CBO} = 10\,\mu A$

$$I_E = 8\text{ mA}$$

From equation $$I_C = \alpha I_E + I_{CBO}$$

$$I_C = 0.99 \times 8\text{ mA} + 10\,\mu\text{A}$$

$$= 7.93\text{ mA}$$

From equation $$I_B = I_E - I_C$$

$$I_B = 8\text{ mA} - 7.93\text{ mA}$$

$$= 70\,\mu\text{A}$$

Ex. 5.4 : *Calculate the values of collector current and emitter current for a transistor with α = 0.98 and I_{CBO} = 5 μA. The base current is measured as 100 μA.*

Sol. : Given : $I_B = 100\,\mu A$, $\alpha = 0.98$ and

We know that, $$I_{CBO} = 5\,\mu\text{A}$$

Thus $$I_B = (1-\alpha) I_E - I_{CBO}$$

$$I_E = \frac{I_B + I_{CBO}}{1-\alpha}$$

$$= \frac{100\,\mu A + 5\,\mu A}{1 - 0.98}$$

$$= \frac{105\,\mu A}{0.02} = 5.25\text{ mA}$$

From equation $I_C = I_E - I_B$ we get,

$$I_C = 5.25\text{ mA} - 100\,\mu A = 5.15\text{ mA}$$

Ex. 5.5 : *For a certain transistor, $\alpha = 0.98$, $I_C = 5\text{ mA}$ and $I_{CBO} = 10\,\mu A$. Find I_B.*

Sol. : Given $I_C = 5$ mA

$$I_{CBO} = 10\,\mu A$$

$$\alpha = 0.98$$

We know that,

$$I_C = \alpha I_E + I_{CBO}$$

$$I_E = \frac{I_C - I_{CBO}}{\alpha}$$

$$= \frac{5\text{ mA} - 10\,\mu A}{0.98}$$

$$= 5.092\text{ mA}$$

From equation $I_B = I_E - I_C$ we get,

$$I_B = 5.092 \times 10^{-3} - 5 \times 10^{-3} = 92\,\mu A$$

5.6.1.2 Common Base Characteristics

To understand complete electrical behaviour of a transistor it is necessary to study the interrelation of the various currents and voltages. These relationships can be plotted graphically and which are commonly known as the **characteristics of transistor**. The most important characteristics of transistor in any configuration are input and output characteristics.

A) Input Characteristics :

It is the curve between input current I_E (emitter current) and input voltage V_{EB} (emitter-base voltage) at constant collector-base voltage V_{CB}. The emitter current is taken along Y-axis and emitter base voltage along X-axis. Fig. 5.16 shows the input characteristics of a typical transistor in common-base configuration.

From this characteristics we can observe the following important points :

1. After the cut-in voltage, the emitter current (I_E) increases rapidly with small increase in emitter-base voltage (V_{EB}). It means that input resistance is very small. Because input resistance is a ratio of change in emitter-base voltage (ΔV_{EB}) to the resulting change in emitter current (ΔI_E) at constant collector-base voltage (V_{CB}), this resistance is also known as the **dynamic input resistance** of the transistor in CB configuration.

Substituting the value of I_B in equation (5.14) we get,

$$\beta = \frac{I_C}{I_E - I_C} \quad \ldots (5.16)$$

Dividing the numerator and denominator of R.H.S. of equation (5.16) by I_E, we get,

$$\beta = \frac{\frac{I_C}{I_E}}{\frac{I_E}{I_E} - \frac{I_C}{I_E}}$$

We know that, $\alpha = \frac{I_C}{I_E}$ from equation (5.15)

$$\therefore \quad \beta = \frac{\alpha}{1-\alpha} \quad \ldots (5.17)$$

b) Dividing the R.H.S. and L.H.S. by $1 + \beta$ we get,

$$\frac{\beta}{1+\beta} = \frac{\frac{\alpha}{1-\alpha}}{1+\beta}$$

By substituting value of β from equation (5.17) in R.H.S. we get,

$$\frac{\beta}{1+\beta} = \frac{\frac{\alpha}{1-\alpha}}{1+\frac{\alpha}{1-\alpha}}$$

$$\frac{\beta}{1+\beta} = \frac{\frac{\alpha}{1-\alpha}}{\frac{1-\alpha+\alpha}{1-\alpha}}$$

Cancelling common denominator terms we get,

$$\frac{\beta}{1+\beta} = \frac{\alpha}{1-\alpha+\alpha} = \alpha$$

$$\therefore \quad \alpha = \frac{\beta}{1+\beta} \quad \ldots (5.18)$$

Ex. 5.6 : *a) Find α for each of the following values of β = 50 and 190*
b) Find β for each of the following values of α = 0.995 and 0.9765

Sol. : a)

$$\alpha = \frac{\beta}{\beta+1}$$

$$\beta = 50, \quad \alpha = \frac{50}{50+1} = 0.9804$$

$$\beta = 190, \quad \alpha = \frac{190}{190+1} = 0.9947$$

b)

$$\beta = \frac{\alpha}{1-\alpha}$$

$$\alpha = 0.995, \quad \beta = \frac{0.995}{1-0.995} = 199$$

$$\alpha = 0.9765, \quad \beta = \frac{0.9765}{1-0.9765} = 41.55$$

Ex. 5.7 : *If the base current in a transistor is 20 μA when the emitter current is 6.4 mA, what are the values of α and β ? Also calculate the collector current.*

Sol. : Given : $I_B = 20\ \mu A$ $I_E = 6.4\ mA$

$$I_C = I_E - I_B$$
$$= 6.4\ mA - 20\ \mu A$$
$$= 6.38\ mA$$

$$\therefore \quad \beta = \frac{I_C}{I_B} = \frac{6.38\ mA}{20\ \mu A}$$
$$= 319$$

$$\alpha = \frac{\beta}{\beta+1} = \frac{319}{319+1}$$
$$= 0.9968$$

Ex. 5.8 : *In a certain transistor, 99.6 % of the carriers injected into the base cross the collector-base junction. If the leakage current is 5 μA and the collector current is 20mA, calculate (i) the value of α (ii) the emitter current.*

Sol. : Given : $I_C = 0.996\, I_E$, $I_{CBO} = 5\ \mu A$, $I_C = 20\ mA$

i)

$$\alpha = \frac{I_C}{I_E} = 0.996$$

$$I_C = \alpha I_E + I_{CBO}$$

$$\therefore \quad I_E = \frac{I_C - I_{CBO}}{\alpha}$$

$$= \frac{20\ mA - 5\ \mu A}{0.996}$$

$$= 20.07\ mA$$

Ex. 5.9 : *The reverse leakage current of the transistor, when connected in common-base configuration is 0.1 μA, while it is 16 μA when the same transistor is connected in common-emitter configuration. Calculate the α and β of the transistor.*

Sol. : Given : $I_{CBO} = 0.1\ \mu A,\ I_{CEO} = 16\ \mu A$

$$I_{CEO} = \frac{1}{1-\alpha} I_{CBO}$$

$$1-\alpha = \frac{I_{CBO}}{I_{CEO}}$$

$$\alpha = 1 - \frac{I_{CBO}}{I_{CEO}} = 0.993$$

$$\beta = \frac{\alpha}{1-\alpha} = \frac{0.993}{1-0.993} = 159$$

5.6.2.3 Common Emitter Characteristics

A) Input Characteristics :

It is the curve between input current I_B (base current) and input voltage V_{BE} (base-emitter voltage) at constant collector-emitter voltage, V_{CE}. The base current is taken along Y-axis and base emitter voltage V_{BE} is taken along X-axis. Fig. 5.27 shows the input characteristics of a typical transistor in common-emitter configuration.

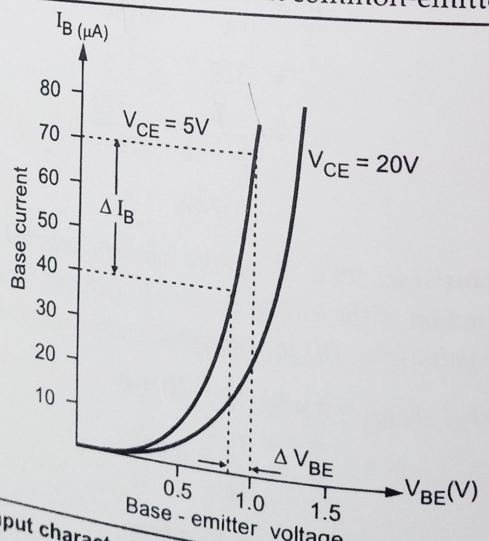

Fig. 5.27 Input characteristics of the transistor in CE configuration

From this characteristics we observe the following important points :

1. As the input to a transistor in the CE configuration is between the base-to-emitter junction, the CE input characteristics resembles a family of forward-biased diode curves. A typical set of CE input characteristics for an n-p-n transistor is shown in Fig. 5.27.