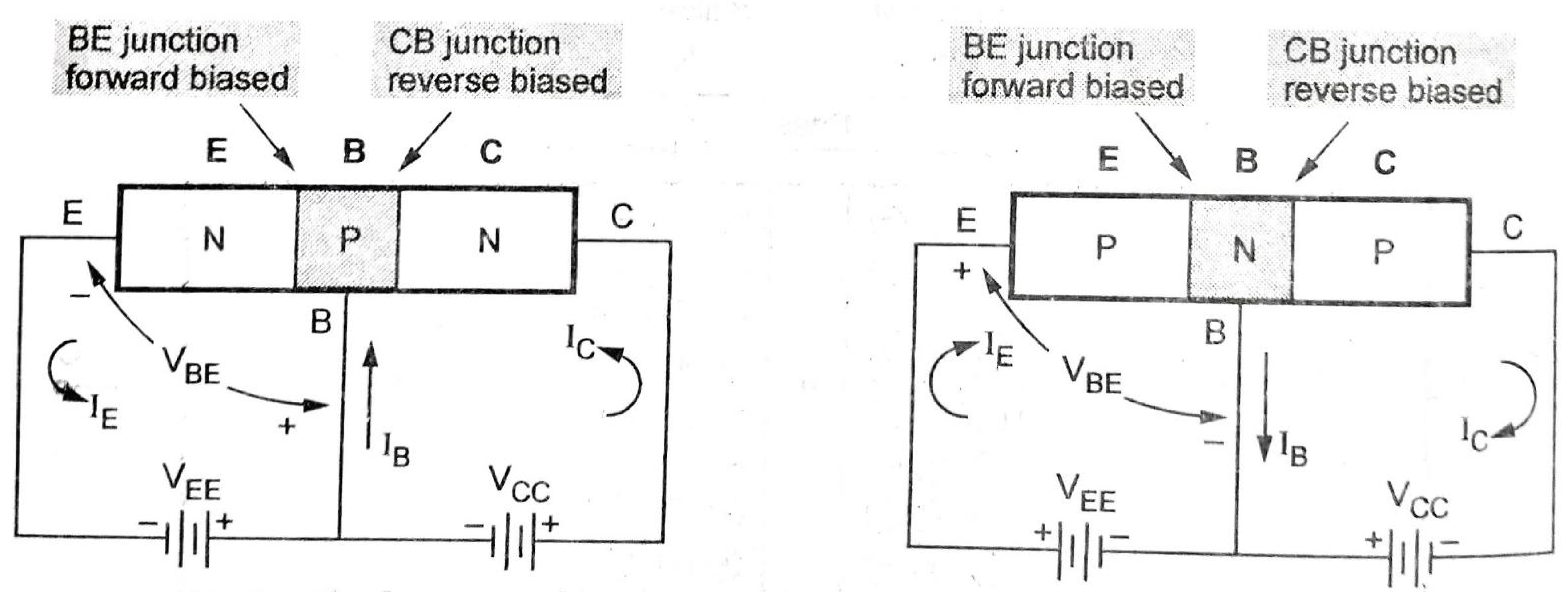
4.3.2 Biased Transistor

- In order to operate transistor properly as an amplifier, it is necessary to correctly bias the two pn junctions with external voltages. Depending upon external bias voltage polarities used, the transistor works in one of the three regions :

  1. *Active region* 2. *Cut-off region* and 3. *Saturation region.*

Region	Emitter-base junction	Collector-base junction
Active	Forward biased	Reverse biased
Cut-off	Reverse biased	Reverse biased
Saturation	Forward biased	Forward biased

- To bias the transistor in its active region, the emitter base junction is forward biased, while the collector-base junction in reverse-biased as shown in Fig. 4.3.3.
- The Fig. 4.3.3 shows the circuit connections for active region for both npn and pnp transistors.



(a) npn **(b) pnp**

Fig. 4.3.3 Transistor forward-reverse bias

- The externally applied bias voltages are V_{EE} and V_{CC}, as shown in Fig. 4.3.3 which bias the transistor in its active region. The operation of the pnp is the same as for the npn except that the roles of the electrons and holes, the bias voltage polarities and the current directions are all reversed.

- Note that in both cases the base-emitter (J_E) junction is forward biased and the collector-base junction (J_C) is reversed biased.

4.3.3 Operation of npn Transistor

- The base to emitter junction is forward biased by the d.c. source V_{EE}. Thus, the depletion region at this junction is reduced. The collector to base junction is reverse biased, increasing depletion region at collector to base junction as shown in Fig. 4.3.4.

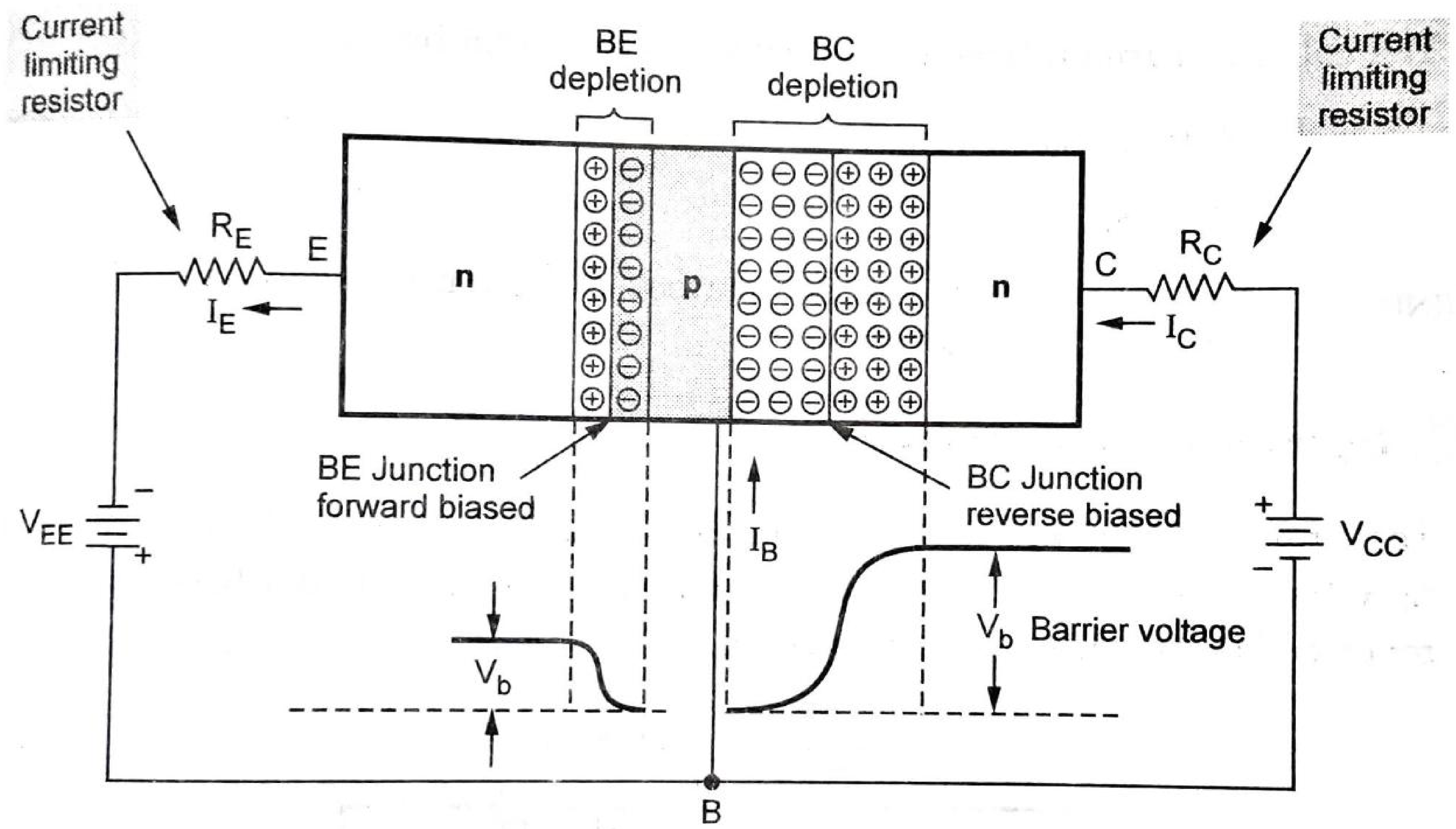


Fig. 4.3.4

- The forward biased EB junction causes the electrons in the n-type emitter to flow towards the base. This constitutes the emitter current I_E. As these electrons flow through the p-type base, they tend to combine with holes in p-region (base).
- Due to light doping, very few of the electrons injected into the base from the emitter recombine with holes to constitute base current, I_B and the remaining large number of electrons cross the base region and move through the collector region to the positive terminal of the external d.c. source.
- This constitutes collector current I_C. Thus the electron flow constitutes the dominant current in an npn transistor.

- Since, the most of the electrons from emitter flow in the collector circuit and very few combine with holes in the base. Thus, the collector current is larger than the base current. The relationship between these current is given by

$$I_E = I_C + I_B$$

- This relationship is also obtained by applying Kirchhoff's current law to the transistor of Fig. 4.3.4.
- Since it is a bipolar device, the collector current comprises two components : **majority** and **minority.**
- The minority current component is called the **leakage current** and is given the symbol I_{CO} (I_C current with emitter terminal open).
- The collector current, therefore, is determined in total by

$$I_C = I_{C\,majority} + I_{CO\,minority}$$

$$= I_{C(INJ)} + I_{CO}$$

$I_{C(INJ)}$: It is an injected collector current due to majority carriers crossing the collector base junction.

4.3.4 Operation of pnp Transistor

- The pnp transistor has its bias voltages V_{EE} and V_{CC} reversed from those in the npn transistor. This is necessary to forward-bias the emitter-base junction and reverse-bias the collector base junction.

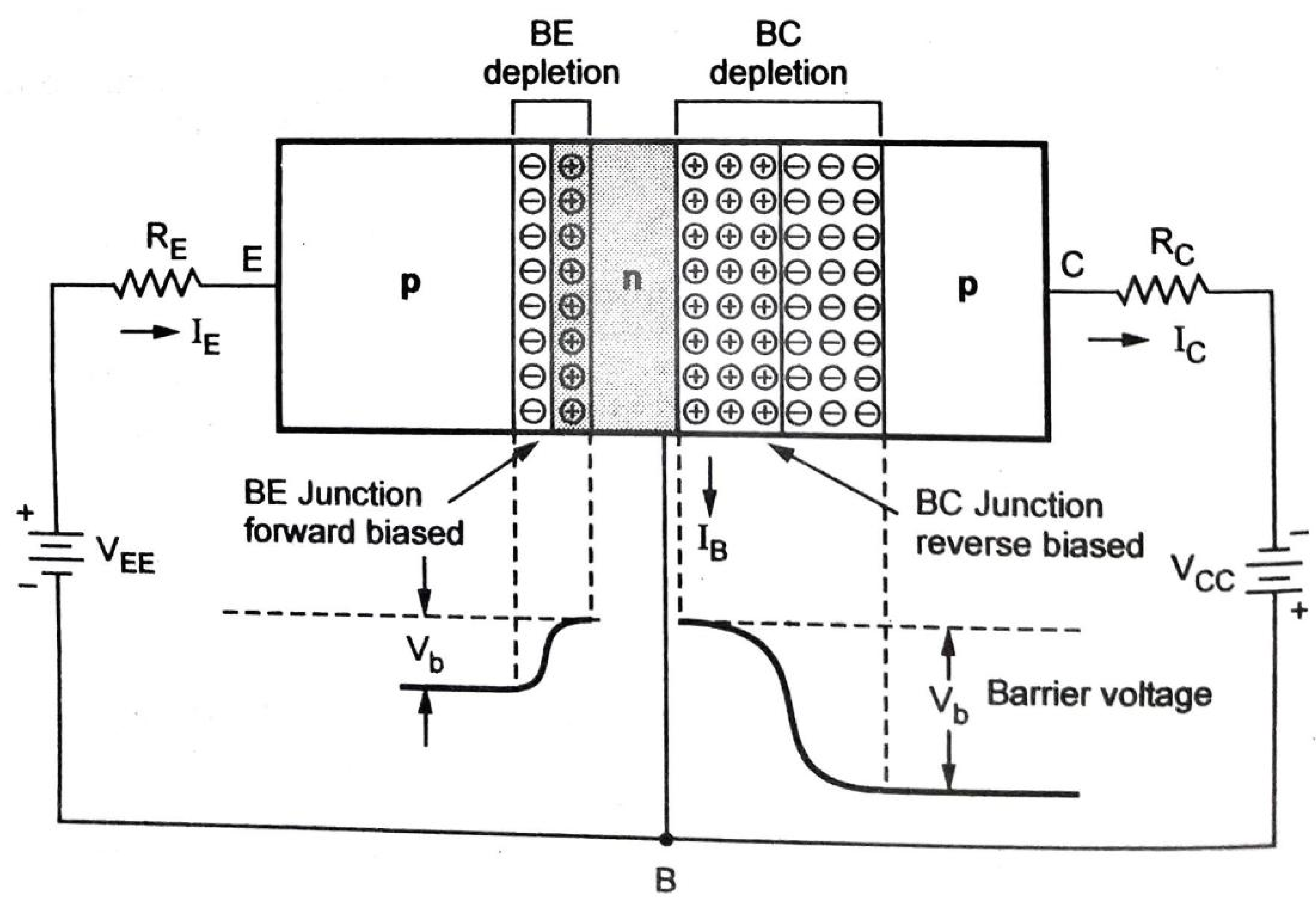


Fig. 4.3.5

- The forward biased EB junction causes the holes in the p-type emitter to flow towards the base. This constitutes the emitter current I_E.
- As these holes flow through the n-type base, they tend to combine with electrons in n-region (base). As the base is very thin and lightly doped, very few of the holes injected into the base from the emitter recombine with electrons to constitute base current, I_B.
- The remaining large number of holes cross the depletion region and move through the collector region to the negative terminal of the external d.c. source. This constitutes collector current I_C. Thus the hole flow constitutes the dominant current in an pnp transistor.

4.3.5 Transistor Voltages

npn Transistor

- The Fig. 4.3.6 shows the terminal voltages and its polarities for an npn transistor. The voltage between base and emitter is denoted as V_{BE}. For V_{BE}, base is positive than emitter because for npn transistor, the base is biased positive with respect to the emitter.

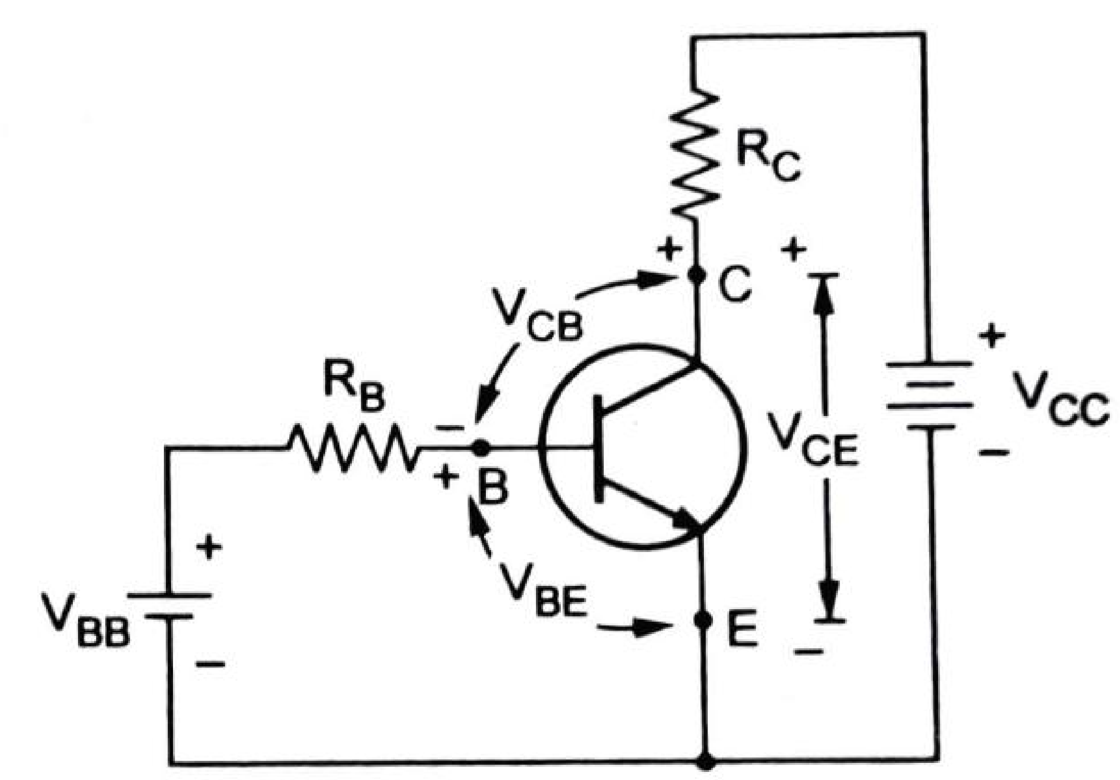


Fig. 4.3.6 Voltage source connections for npn transistor

- The voltage between the collector and the emitter is denoted as V_{CE} and the voltage between the collector and the base is denoted as V_{CB}. Since collector is positive with respect to base and emitter the polarities are as shown in the Fig. 4.3.6.
- The Fig. 4.3.6 shows the npn transistor with voltage source connections. The voltage sources are connected to the transistor with series resistors. These resistors are called **current limiting resistors.**
- The base supply voltage V_{BB} is connected via resistor R_B, and the collector supply voltage, V_{CC} is connected via resistor R_C.
- The negative terminals of both the supply voltages are connected to emitter terminal of the transistor.
- To make CB junction reverse biased, the supply voltage V_{CC} is always much larger than supply voltage V_{BB}.

pnp Transistor

- The Fig. 4.3.7 shows the terminal voltages and its polarities for a pnp transistor. For a pnp transistor, the base is biased negative with respect to the emitter, and the collector is made more negative than the base.

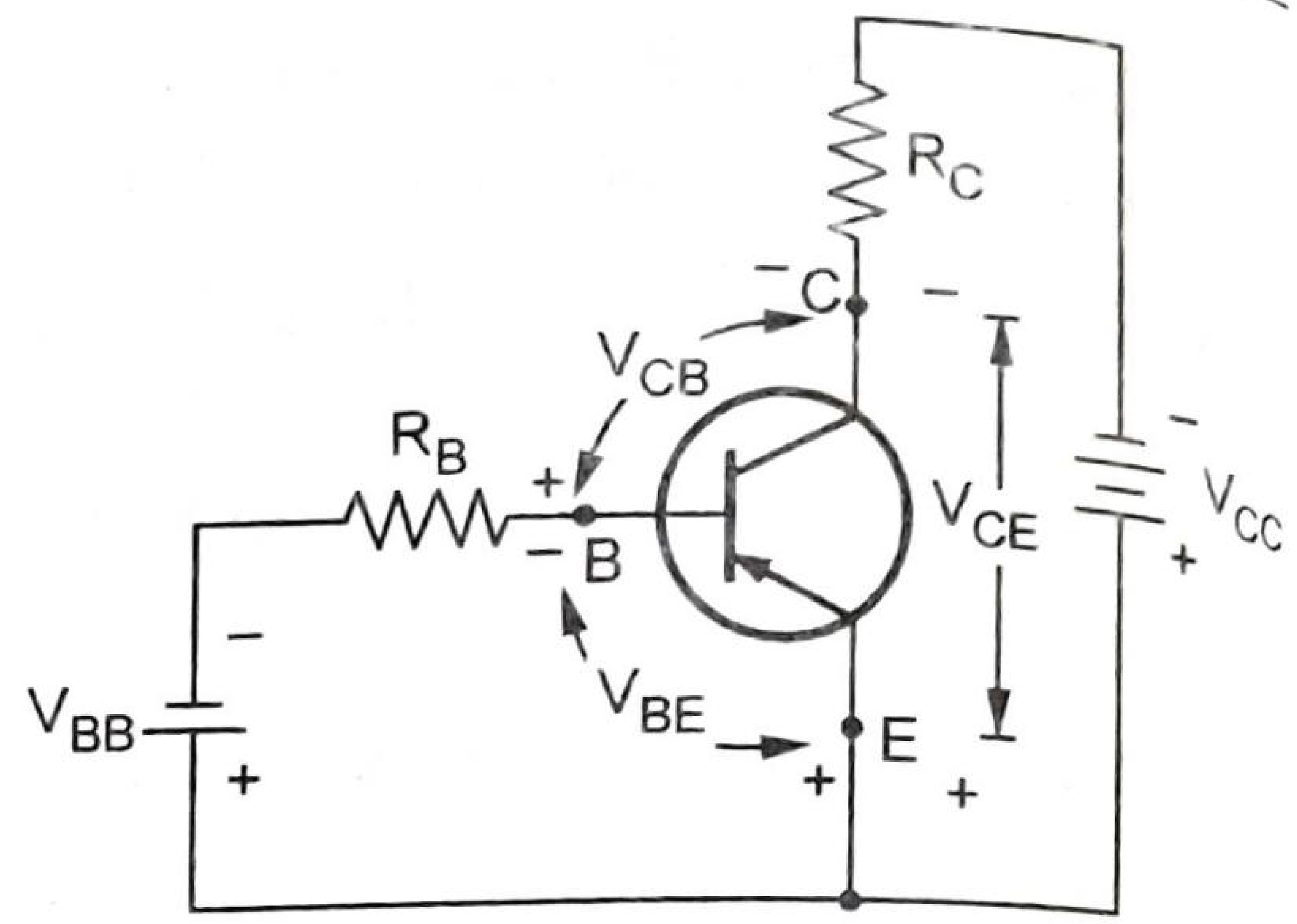


Fig. 4.3.7 Voltage source connection for pnp transistor

- The Fig. 4.3.7 shows the pnp transistor with voltage source connections. Like npn transistor voltage sources are connected with series resistors. The source voltage positive terminals are connected at the emitter with V_{CC} larger than V_{BB} to keep collector-base junction reverse biased.

Junction Voltages

- In different conditions such as active, saturation and cutoff there are different junction voltages. The junction voltages for a typical npn transistor at 25 °C are given in the Table 4.3.1.

Type	$V_{CE\ sat}$	$V_{BE\ sat}$	$V_{BE\ active}$	$V_{BE\ cutin}$	$V_{BE\ cutoff}$
Si	0.2	0.8	0.7	0.5	0.0
Ge	0.1	0.3	0.2	0.1	– 0.1

Table 4.3.1 Typical npn transistor junction voltages at 25 °C

- The entries in the table are appropriate for an npn transistor. For pnp transistor the signs of all entries should be reversed.