# CSE-1102

## Analog Electronics

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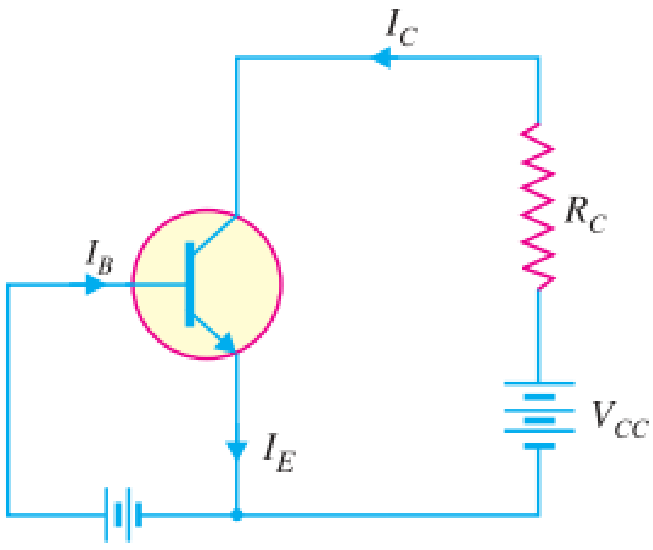
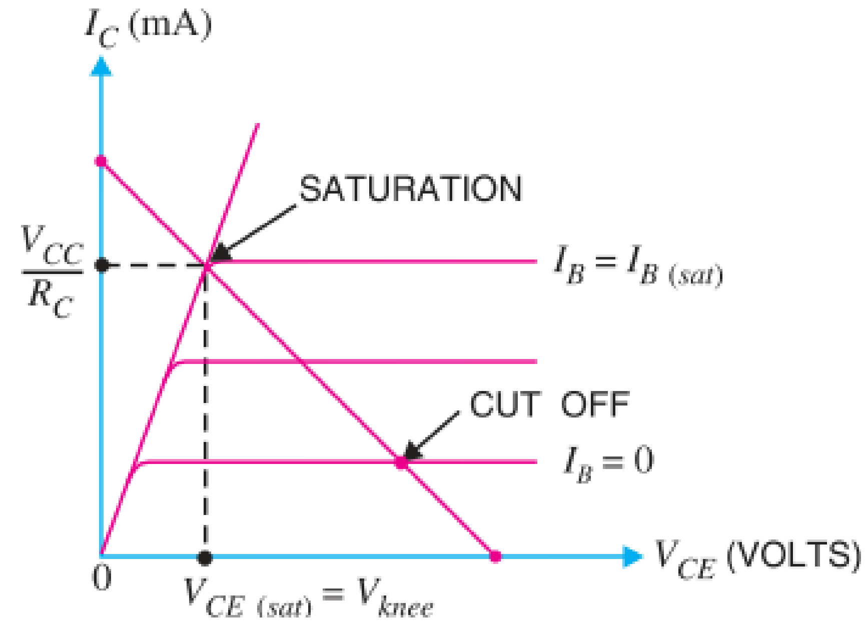
# CE Transistor Characteristics



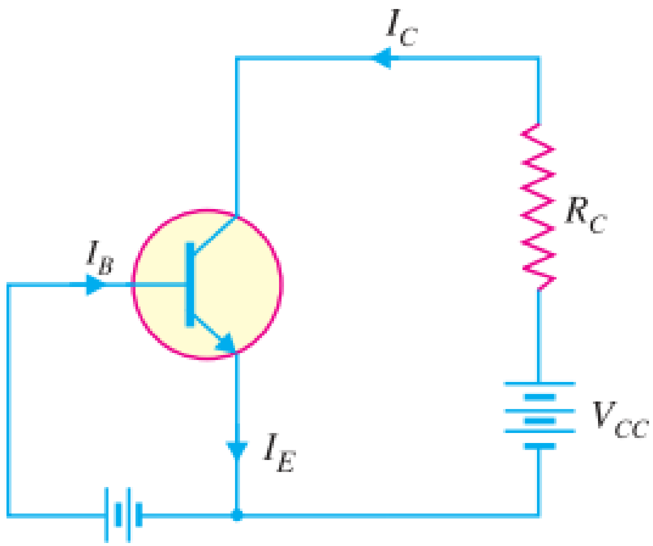



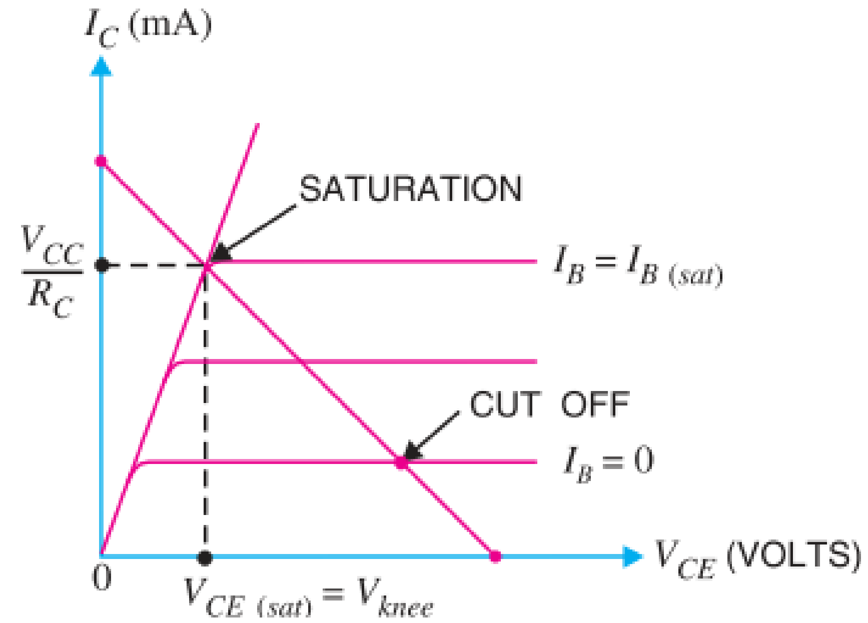

**Cut off:** The point where the load line intersects the $I_B$= 0 curve is known as cut off. At cut off, the base-emitter junction no longer remains forward biased and normal transistor action is lost. $V_{CE(cut\ off)}=V_{CC}$

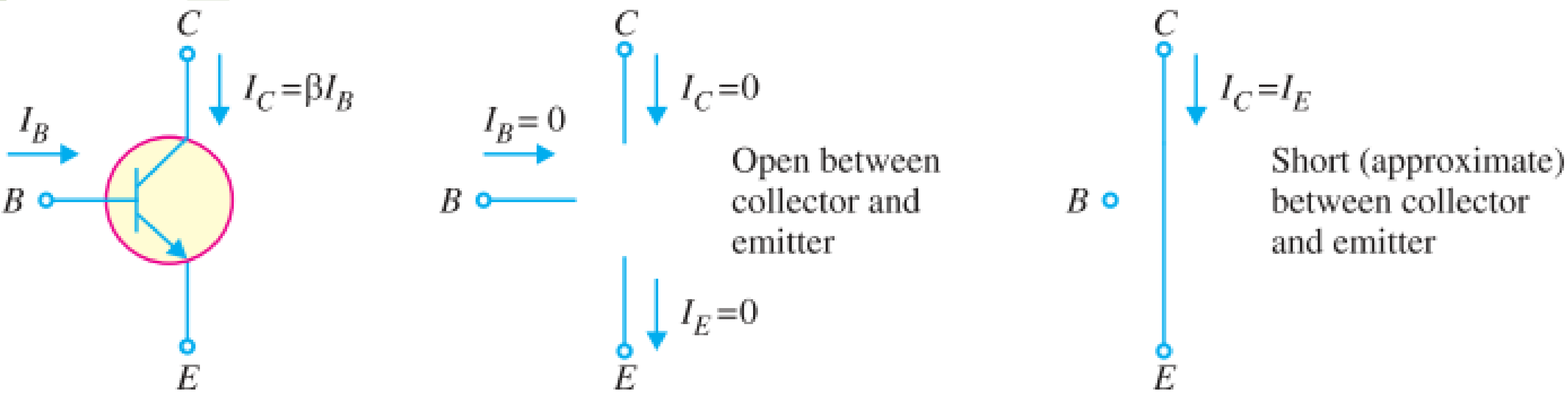
**Saturation:** The point where the load line intersects the $I_B=I_{B(sat)}$ curve is called saturation. At this point, the base current is maximum and so is the collector current. At saturation, collector-base junction no longer remains reverse biased and normal transistor action is lost.

**Active region**: The region between cut off and saturation is known as active region. In the active region, collector-base junction remains reverse biased while base-emitter junction remains forward biased. Consequently, the transistor will function normally in this region.

# CE Transistor Characteristics



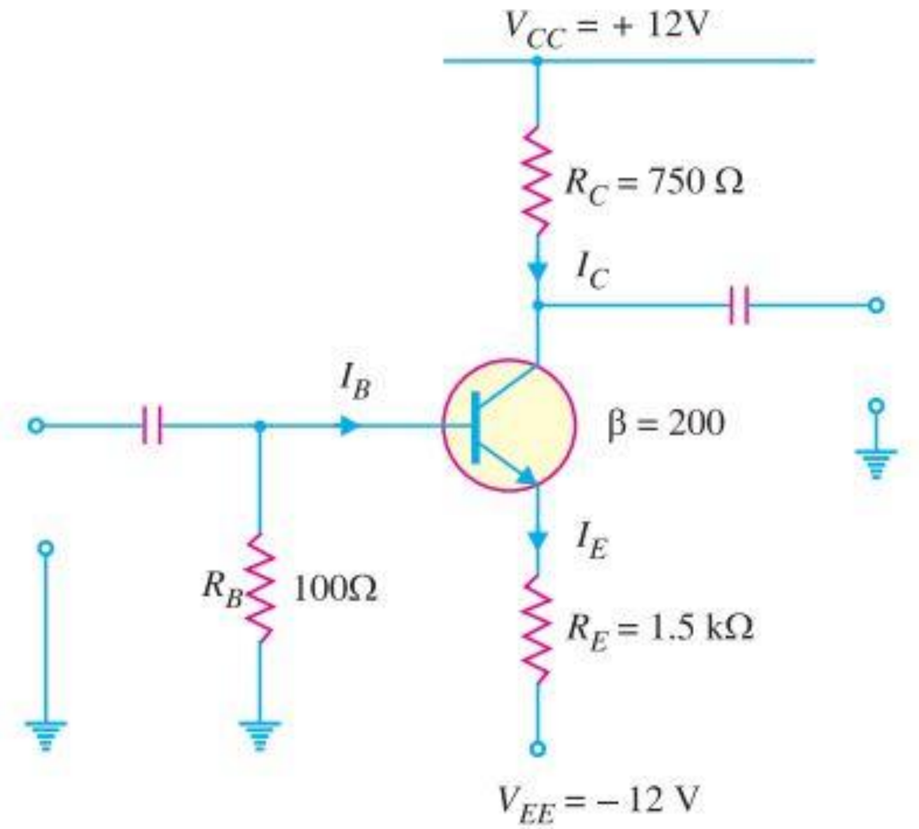




(i) ACTIVE (ii) CUT-OFF (iii) SATURATED

P3

**Example 8.32.** *Determine the values of $V_{CE\,(off)}$ and $I_{C\,(sat)}$ for the circuit shown in Fig. 8.53.*



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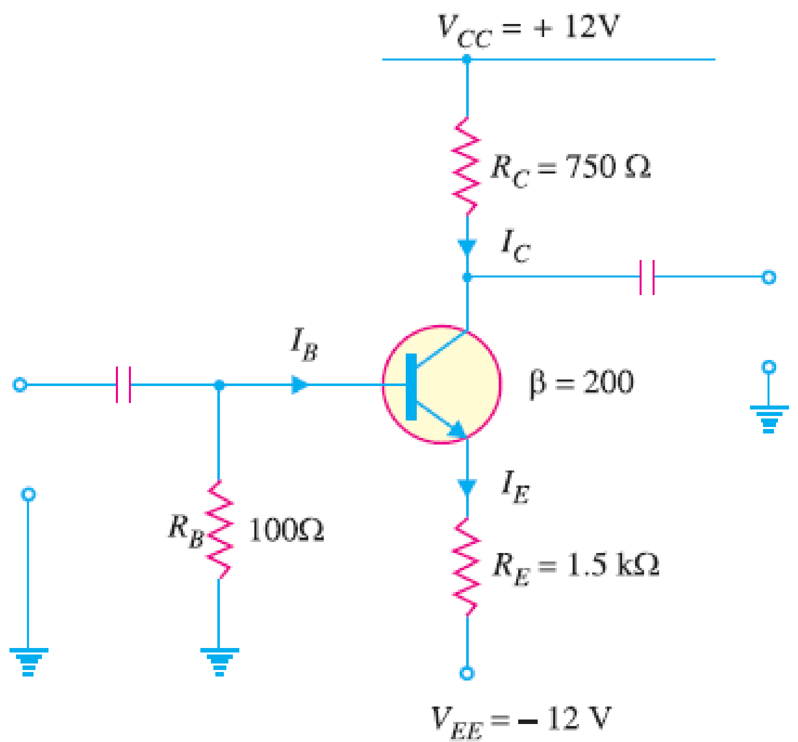



**Fig. 8.53**

**Solution.** Applying Kirchhoff's voltage law to the collector side of the circuit in Fig. 8.53, we have,

$$V_{CC} - I_C R_C - V_{CE} - {}^*I_C R_E + V_{EE} = 0$$

or $$V_{CE} = V_{CC} + V_{EE} - I_C (R_C + R_E) \quad \text{... } (i)$$

We have $V_{CE\,(off)}$ when $I_C = 0$. Therefore, putting $I_C = 0$ in eq. (*i*), we have,

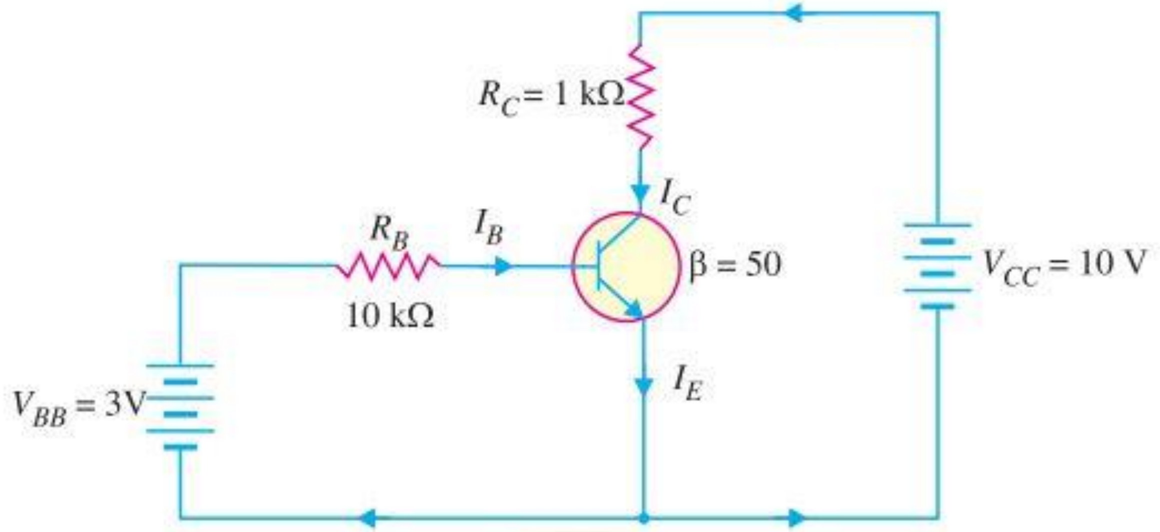
$$V_{CE\,(off)} = V_{CC} + V_{EE} = 12 + 12 = \mathbf{24V}$$

We have $I_{C\,(sat)}$ when $V_{CE} = 0$.

$$\therefore \quad I_{C\,(sat)} = \frac{V_{CC} + V_{EE}}{R_C + R_E} = \frac{(12+12)\,V}{(750+1500)\,\Omega} = \mathbf{10.67\ mA}$$

# Problem

**Example 8.33.** *Determine whether or not the transistor in Fig. 8.54 is in stauration. Assume $V_{knee} = 0.2V$.*



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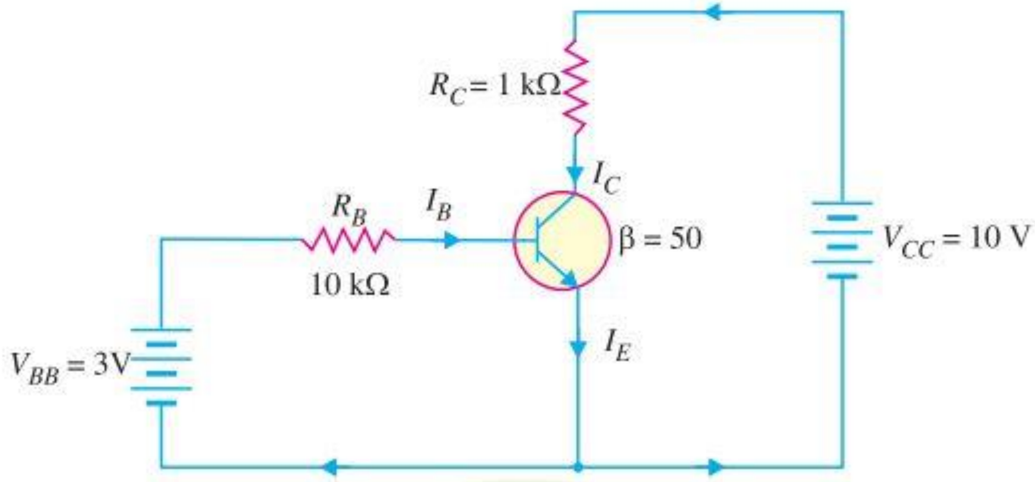



$$I_{C\,(sat)} = \frac{V_{CC} - V_{knee}}{R_C} = \frac{10\,V - 0.2\,V}{1\,k\Omega} = \frac{9.8\,V}{1\,k\Omega} = 9.8 \text{ mA}$$

Now we shall see if $I_B$ is large enough to produce $I_{C\,(sat)}$.

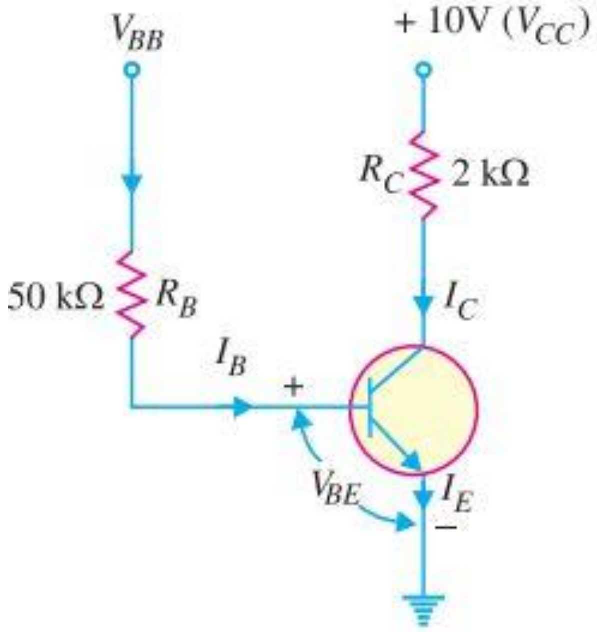
Now $$I_B = \frac{V_{BB} - V_{BE}}{R_B} = \frac{3V - 0.7V}{10\,k\Omega} = \frac{2.3\,V}{10\,k\Omega} = 0.23 \text{ mA}$$

$\therefore$ $$I_C = \beta I_B = 50 \times 0.23 = 11.5 \text{ mA}$$

This shows that with specified β, this base current (= 0.23 mA) is capable of producing $I_C$ greater than $I_{C\,(sat)}$. Therefore, the transistor is **saturated.** In fact, the collector current value of 11. 5 mA is never reached. If the base current value corresponding to $I_{C\,(sat)}$ is increased, the collector current remains at the saturated value (= 9.8 mA).

# Problem

**Example 8.35.** *For the circuit in Fig. 8.57, find the base supply voltage ($V_{BB}$) that just puts the transistor into saturation. Assume $\beta = 200$.*



**Example 8.35.** *For the circuit in Fig. 8.57, find the base supply voltage ($V_{BB}$) that just puts the transistor into saturation. Assume $\beta = 200$.*

**Solution.** When transistor first goes into saturation, we can assume that the collector shorts to the emitter (*i.e.* $V_{CE} = 0$) but the collector current is still β times the base current.

$$I_{C(sat)} = \frac{V_{CC} - V_{CE}}{R_C} = \frac{V_{CC} - 0}{R_C}$$

$$= \frac{10\,V - 0}{2\,k\Omega} = 5 \text{ mA}$$

The base current $I_B$ corresponding to $I_{C\,(sat)}$ (=5 mA) is

$$I_B = \frac{I_{C\,(sat)}}{\beta} = \frac{5\,mA}{200} = 0.025 \text{ mA}$$

Applying Kirchhoff's voltage law to the base circuit, we have,

$$V_{BB} - I_B R_B - V_{BE} = 0$$

or $$V_{BB} = V_{BE} + I_B R_B$$

$$= 0.7\text{V} + 0.025 \text{ mA} \times 50 \text{ k}\Omega = 0.7 + 1.25 = 1.95\text{V}$$

Therefore, for $V_{BB} \geq 1.95$, the transistor will be in *saturation.*

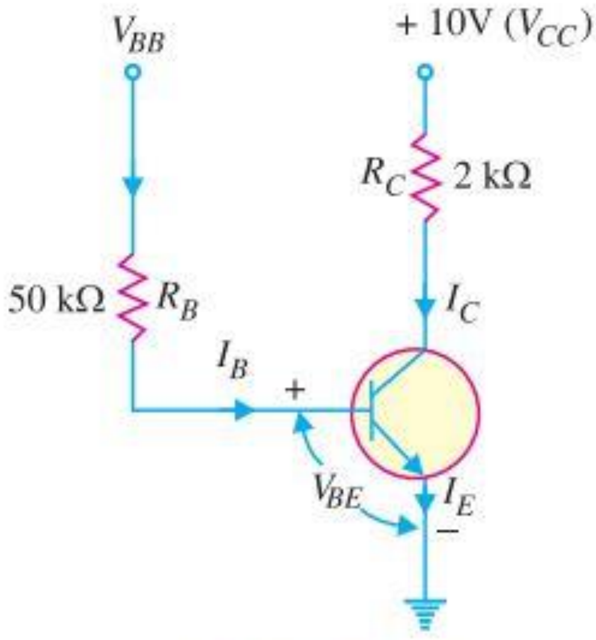
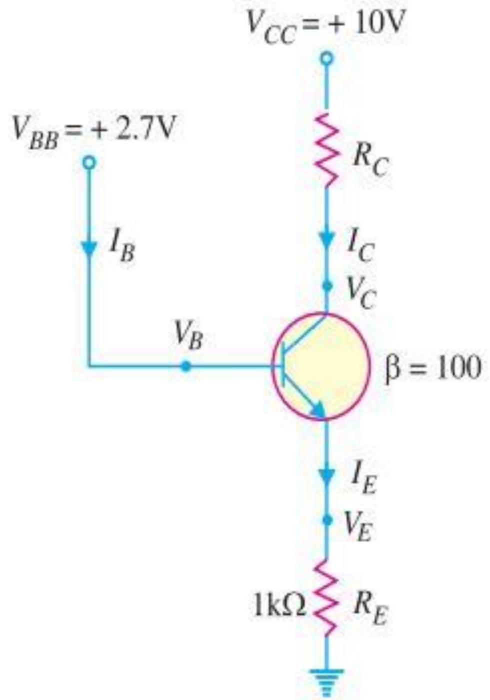



Fig. 8.57

# Problem

**Example. 8.36.** *Determine the state of the transistor in Fig. 8.58 for the following values of collector resistor :*

*(i)* $R_C = 2\ k\Omega$ *(ii)* $R_C = 4\ k\Omega$ *(iii)* $R_C = 8\ k\Omega$



**Example. 8.36.** *Determine the state of the transistor in Fig. 8.58 for the following values of collector resistor :*

*(i)* $R_C = 2\ k\Omega$ *(ii)* $R_C = 4\ k\Omega$ *(iii)* $R_C = 8\ k\Omega$

**Solution.** Since $I_E$ does not depend on the value of the collector resistor $R_C$, the emitter current ($I_E$) is the same for all three parts.

Emitter voltage, $V_E = V_B - V_{BE} = V_{BB} - V_{BE}$

$= 2.7\text{V} - 0.7\ \text{V} = 2\text{V}$

Also $$I_E = \frac{V_E}{R_E} = \frac{2V}{1\ k\Omega} = 2\ \text{mA}$$

**(i) When $R_C$ = 2 kΩ.** Suppose the transistor is active.

$\therefore \quad I_C = I_E = 2\ \text{mA}$

$\therefore \quad I_B = I_C/\beta = 2\ \text{mA}/100 = 0.02\ \text{mA}$

Collector voltage, $V_C = V_{CC} - I_C R_C$

$= 10V - 2\text{ mA} \times 2\text{ k}\Omega = 10V - 4V = 6V$

Since $V_C$ (= 6V) is greater than $V_E$ (= 2V), the transistor is **active.** Therefore, our assumption that transistor is active is correct.

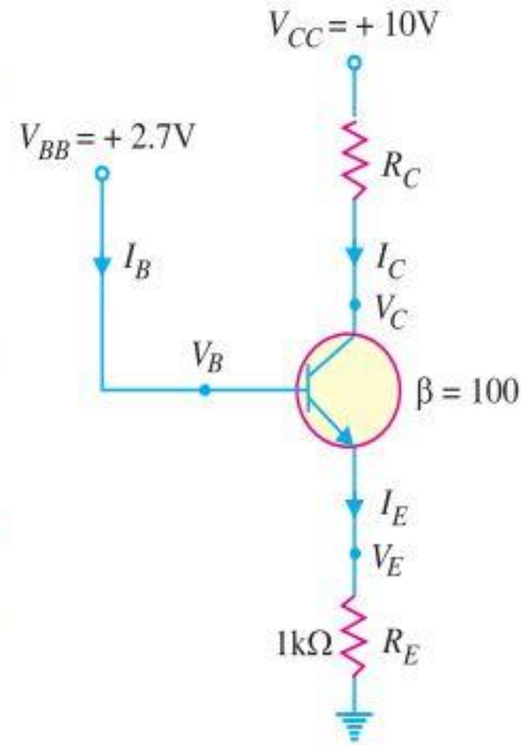


**Fig. 8.58**

**(*ii*) When $R_C = 4\text{ k}\Omega$.** Suppose the transistor is active.

$\therefore \quad I_C = 2\text{mA}$ and $I_B = 0.02\text{ mA}$ ... as found above

Collector voltage, $V_C = V_{CC} - I_C R_C$

$= 10V - 2\text{ mA} \times 4\text{ k}\Omega = 10V - 8V = 2V$

Since $V_C = V_E$, the transistor is just at the edge of **saturation.** We know that at the edge of saturation, the relation between the transistor currents is the same as in the **active state.** Both answers are correct.

**(*iii*) When $R_C = 8\text{ k}\Omega$.** Suppose the transistor is active.

$\therefore \quad I_C = 2\text{mA}\,;\, I_B = 0.02\text{ mA}$ ... as found earlier.

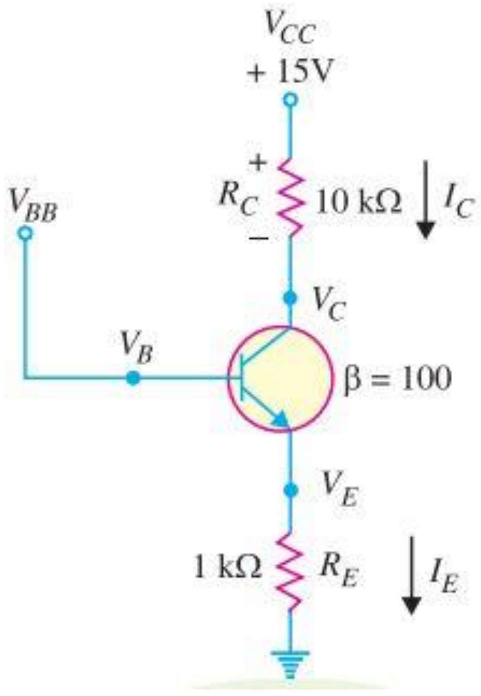
Collector voltage, $V_C = V_{CC} - I_C R_C$

$= 10V - 2\text{ mA} \times 8\text{ k}\Omega = 10V - 16V = -6V$

Since $V_C < V_E$, the transistor is **saturated** and our assumption is not correct.

# Problem

**Example 8.37.** *In the circuit shown in Fig. 8.59, $V_{BB}$ is set equal to the following values :*
*(i) $V_{BB} = 0.5V$ (ii) $V_{BB} = 1.5V$ (iii) $V_{BB} = 3V$*
*Determine the state of the transistor for each value of the base supply voltage $V_{BB}$.*



**Example 8.37.** *In the circuit shown in Fig. 8.59, $V_{BB}$ is set equal to the following values :*
*(i) $V_{BB} = 0.5V$ (ii) $V_{BB} = 1.5V$ (iii) $V_{BB} = 3V$*

*Determine the state of the transistor for each value of the base supply voltage $V_{BB}$.*

**Solution.** The state of the transistor also depends on the base supply voltage $V_{BB}$.

**(i) For $V_{BB} = 0.5V$**

Because the base voltage $V_B$ (= $V_{BB}$ = 0.5V) is less than 0.7V, the transistor is **cut-off.**

**(ii) For $V_{BB} = 1.5V$**

The base voltage $V_B$ controls the emitter voltage $V_E$ which controls the emitter current $I_E$.

Now $$V_E = V_B - 0.7V = 1.5V - 0.7V = 0.8V$$

$$\therefore \quad I_E = \frac{V_E}{R_E} = \frac{0.8\,V}{1\,k\Omega} = 0.8 \text{ mA}$$

If the transistor is active, we have,

$$I_C = I_E = 0.8 \text{ mA and } I_B = I_C/\beta = 0.8/100 = 0.008 \text{ mA}$$

$\therefore$ Collector voltage, $V_C = V_{CC} - I_C R_C$

$$= 15V - 0.8 \text{ mA} \times 10 \text{ k}\Omega = 15V - 8V = 7V$$

Since $V_C > V_E$, the transistor is **active** and our assumption is correct.

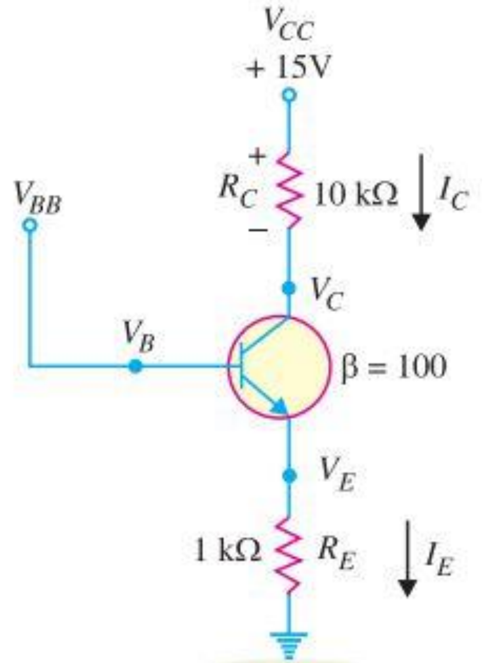



**Fig. 8.59**

**(*iii*) For $V_{BB} = 3V$**

$$V_E = V_B - 0.7V = 3V - 0.7V = 2.3V$$

$$\therefore \quad I_E = \frac{V_E}{R_E} = \frac{2.3\,V}{1\,k\Omega} = 2.3\text{ mA}$$

Assuming the transistor is active, we have,

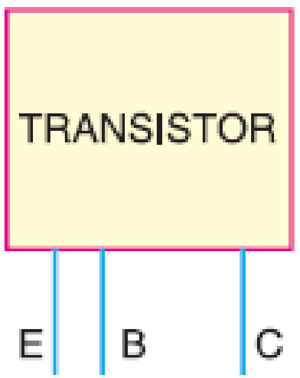
$$I_C = I_E = 2.3\text{ mA} \quad ; \quad I_B = I_C/\beta = 2.3/100 = 0.023\text{ mA}$$

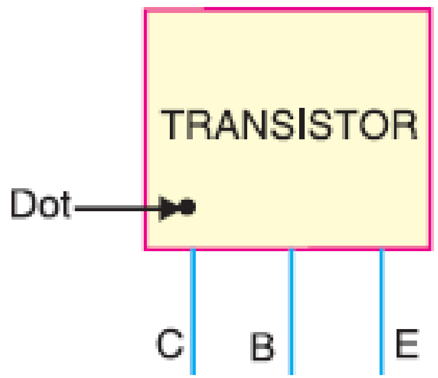
Collector voltage, $V_C = V_{CC} - I_C R_C$

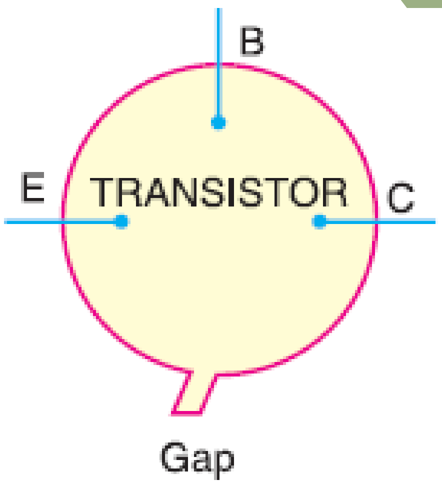
$= 15V - 2.3\text{ mA} \times 10\text{ k}\Omega = 15V - 23V = -8V$

Since $V_C < V_E$, the transistor is **saturated** and our assumption is not correct.

# Transistor Lead Identification




- **When the leads of a transistor are in the same plane and unevenly spaced,** The central lead is the base lead. The collector lead is identified by the larger spacing existing between it and the base lead. The remaining lead is the emitter.
- **When the leads of a transistor are in the same plane but evenly spaced,** the central lead is the base, the lead identified by dot is the collector and the remaining lead is the emitter.
- **When the leads of a transistor are spaced around the circumference of a circle**, the three leads are generally in E-B-C order clockwise from a gap.

# Thank You All