DC Biasing – BJTs

Topic 4 (Chapter 4)

(Some materials are from Malvino’s book)

Biasing

Biasing: Applying DC voltages to a transistor in order to turn it on so that it can amplify AC signals.

The Three Operating Regions

Active or Linear Region Operation

- Base–Emitter junction is forward biased
- Base–Collector junction is reverse biased
- BJT works as an Amplifier

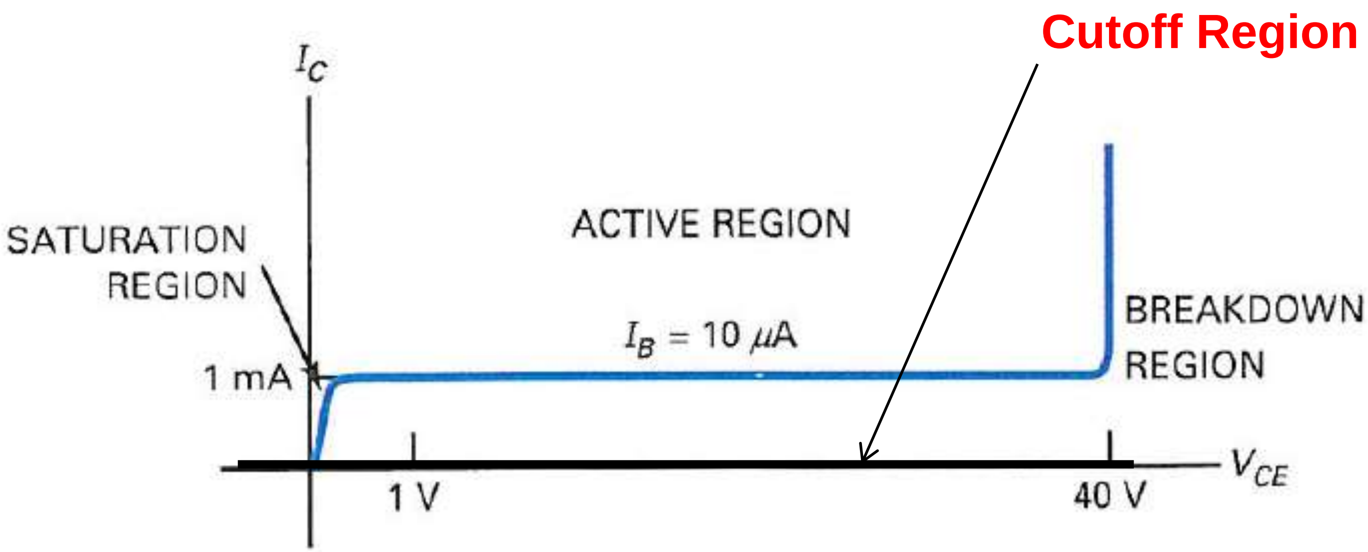
Cutoff Region Operation

- Base–Emitter junction is reverse biased
- Base–Collector junction is reverse biased
- BJT works as an OFF Switch

Saturation Region Operation

- Base–Emitter junction is forward biased
- Base–Collector junction is forward biased or near forward bias
- BJT works as an ON Switch

Regions of operation



1. ***Active** - - - used for <u>linear</u> amplification*
2. **Cutoff - - - used in <u>switching</u> applications (OFF)**
3. **Saturation - - - used in <u>switching</u> applications (ON)**

- **Breakdown - - - can <u>destroy</u> the transistor and should be avoided**

DC Biasing Circuits

Fixed-bias or Base-Bias

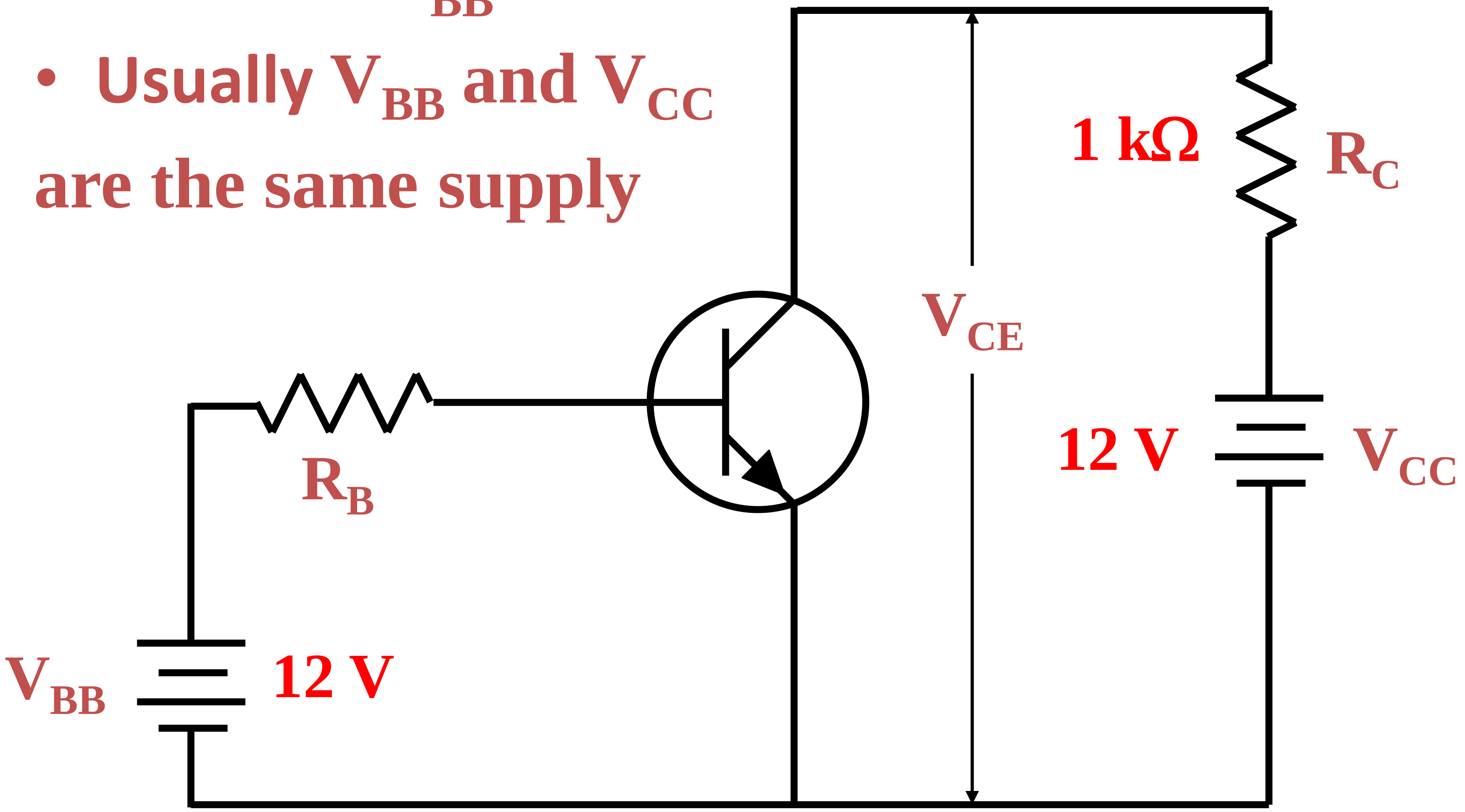
Emitter Bias

Voltage divider bias circuit

DC bias with voltage feedback

4.3 Base-Bias or Fixed-Bias

- Setting up a fixed value of **base current**
- Base current remains constant for given values of V_{BB}
- Usually V_{BB} and V_{CC} are the same supply



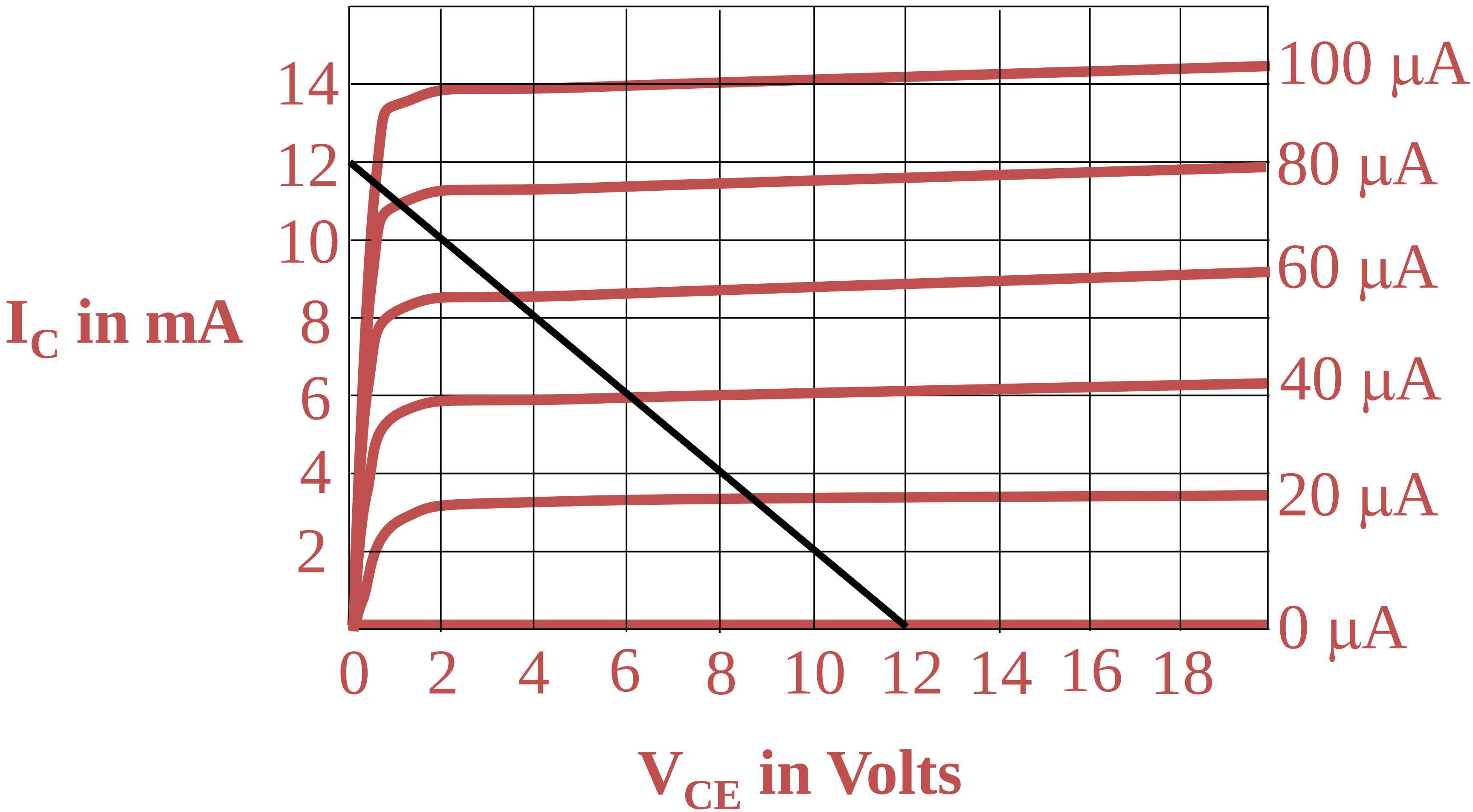
Load line

- A visual summary of all the possible transistor operating points
- Connects saturation current (I_{Csat}) to cutoff voltage ($V_{CEcutoff}$)

Load line

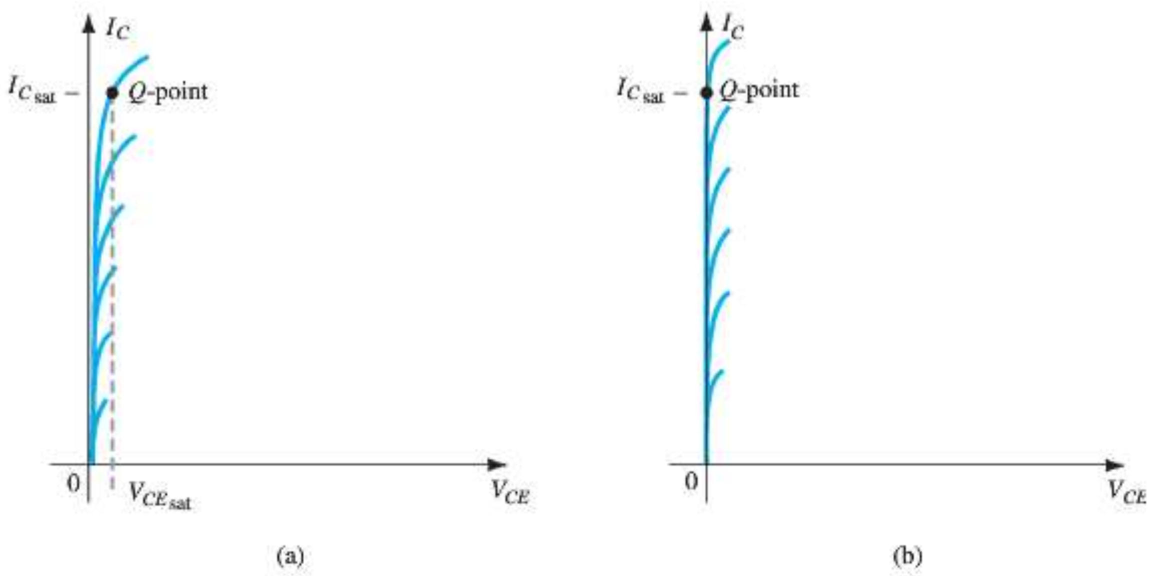
$$I_C = \frac{V_{CC} - V_{CE}}{R_C}$$

A graph of this equation produces a load line.



Saturation

When the transistor is operating in **saturation**, current through the transistor is at its *maximum* possible value.

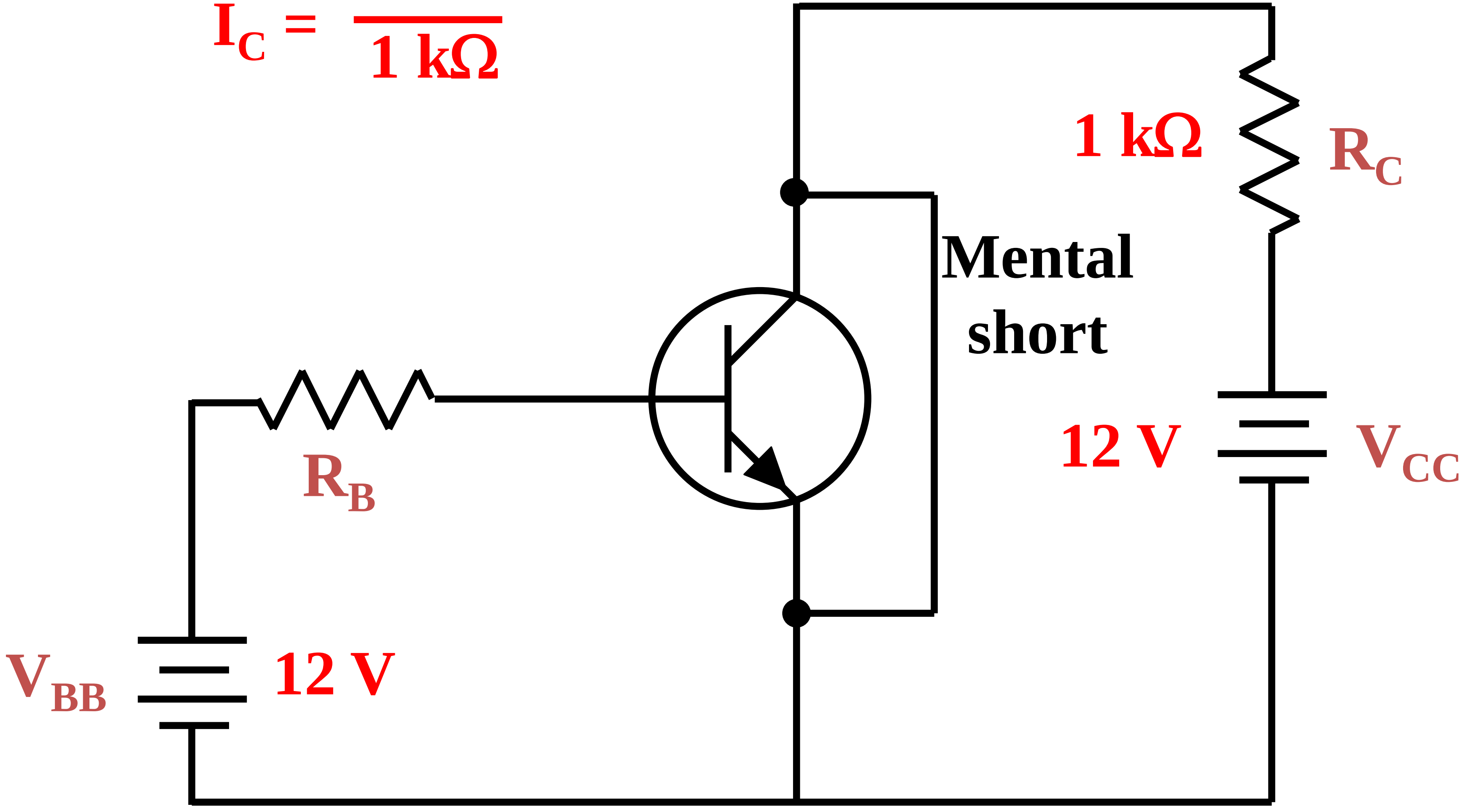


$$I_{Csat} = \frac{V_{CC}}{R_C}$$

$$V_{CE} \cong 0\ V$$

Understanding Saturation

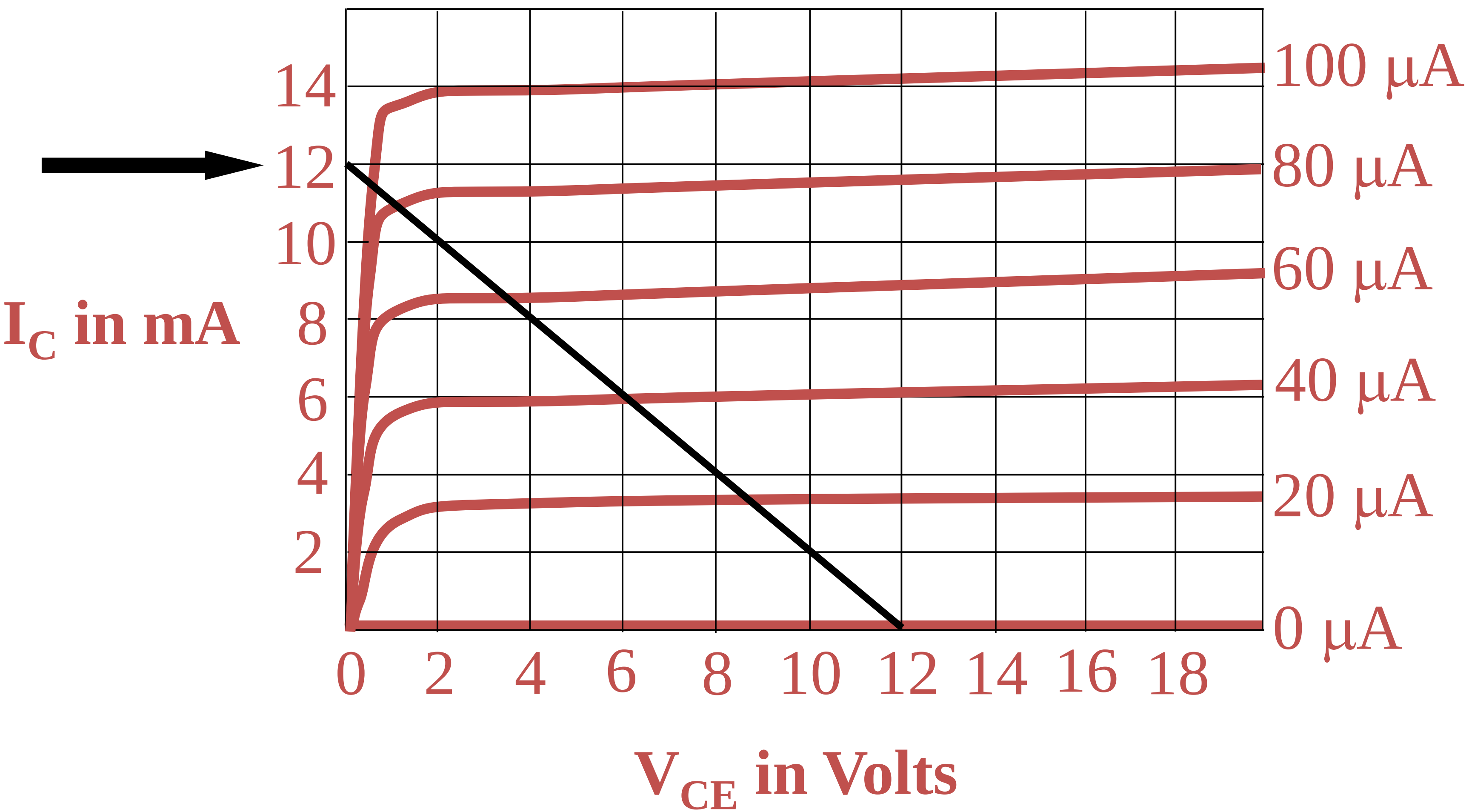
$$I_C = \frac{12\ V}{1\ k\Omega}$$



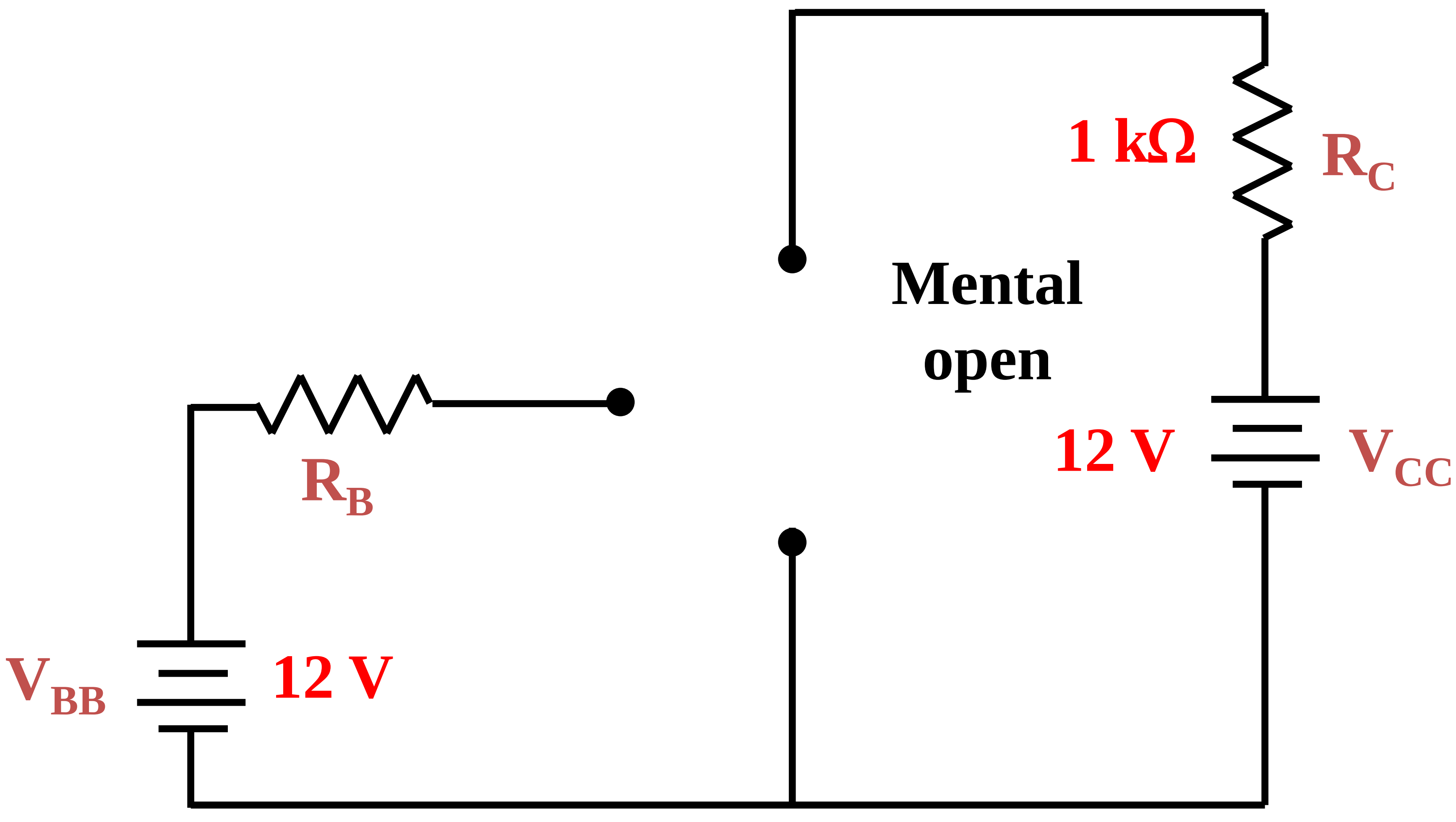
Understanding Saturation

$$I_C = \frac{12\ \text{V}}{1\ \text{k}\Omega} = 12\ \text{mA}$$

This is the Saturation (maximum) current.

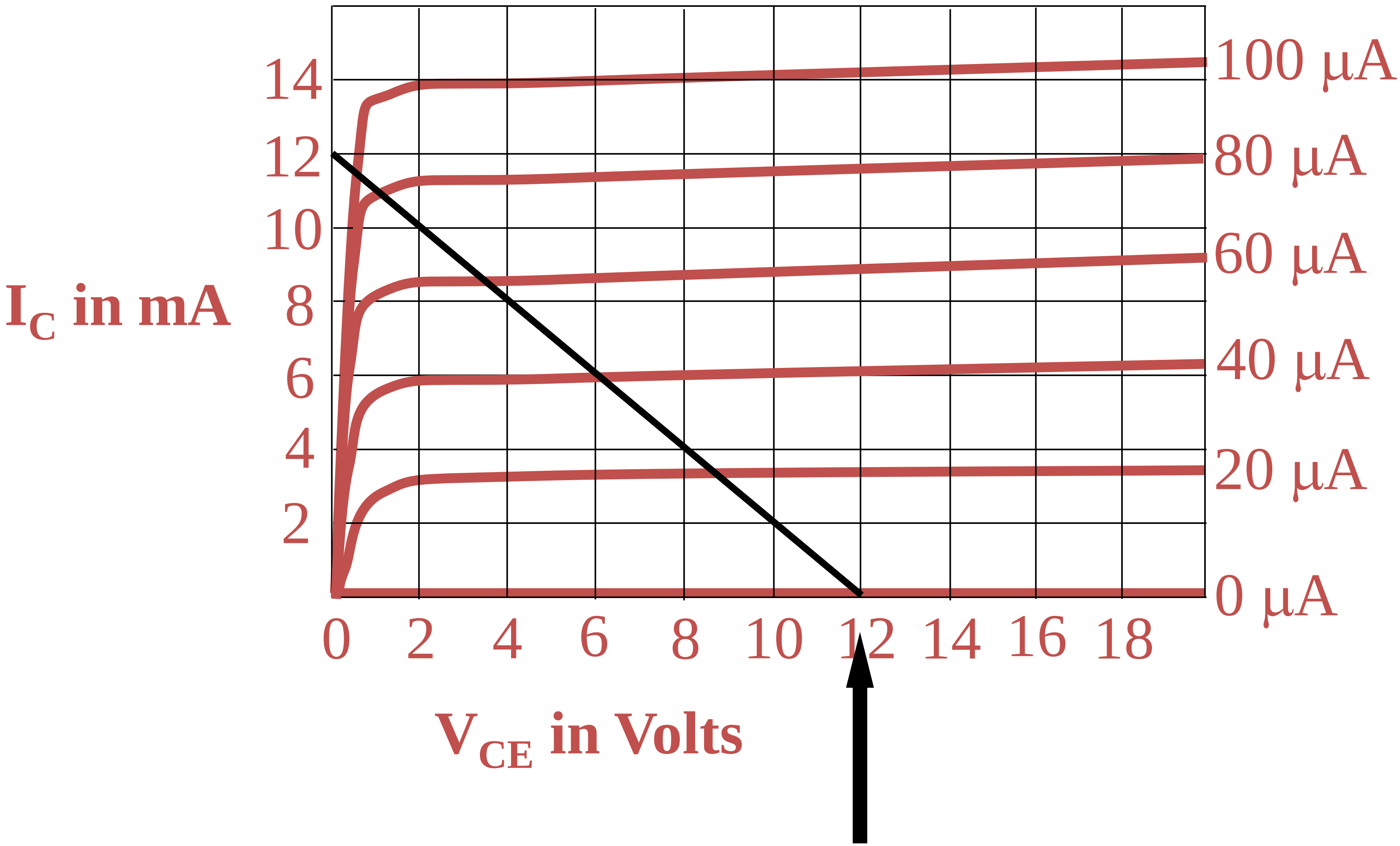


Understanding Cutoff



Understanding Cutoff

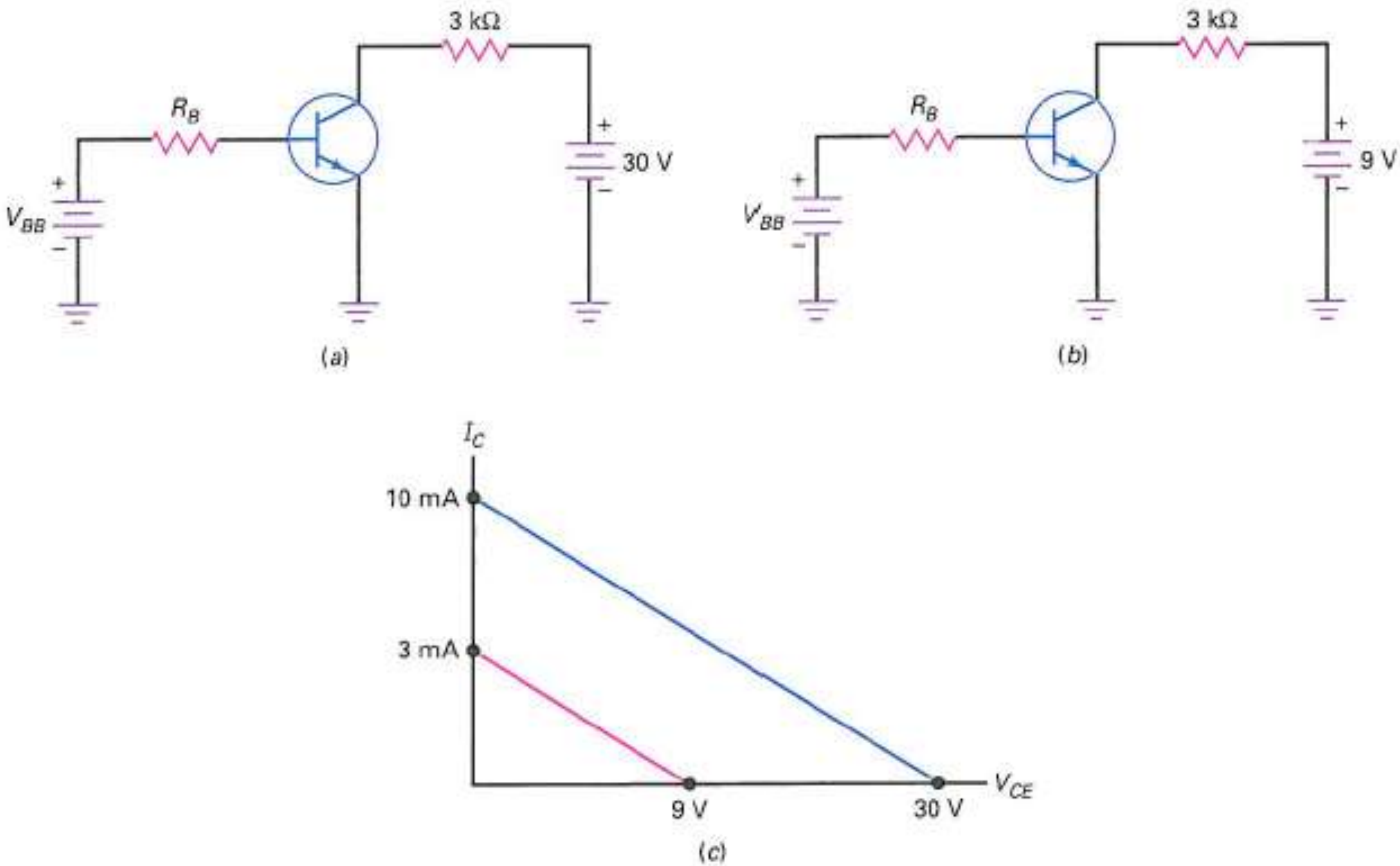
$$V_{CE(cutoff)} = V_{CC}$$



Example 7-1

What are the saturation current and the cutoff voltage in Fig. 7-4*a*?

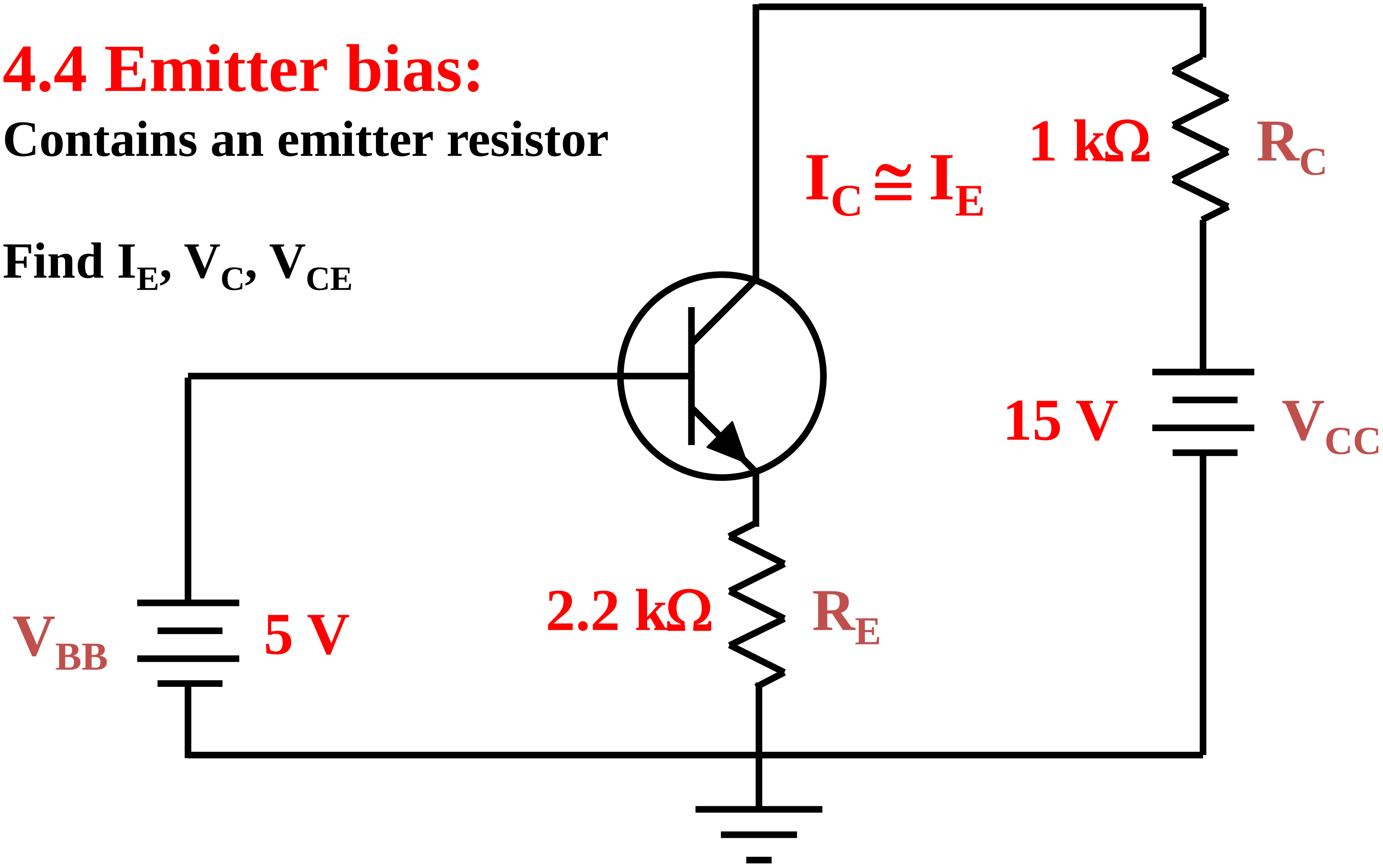
Calculate the saturation and cutoff values for Fig. 7-4*b*.



4.4 Emitter bias:

Contains an emitter resistor

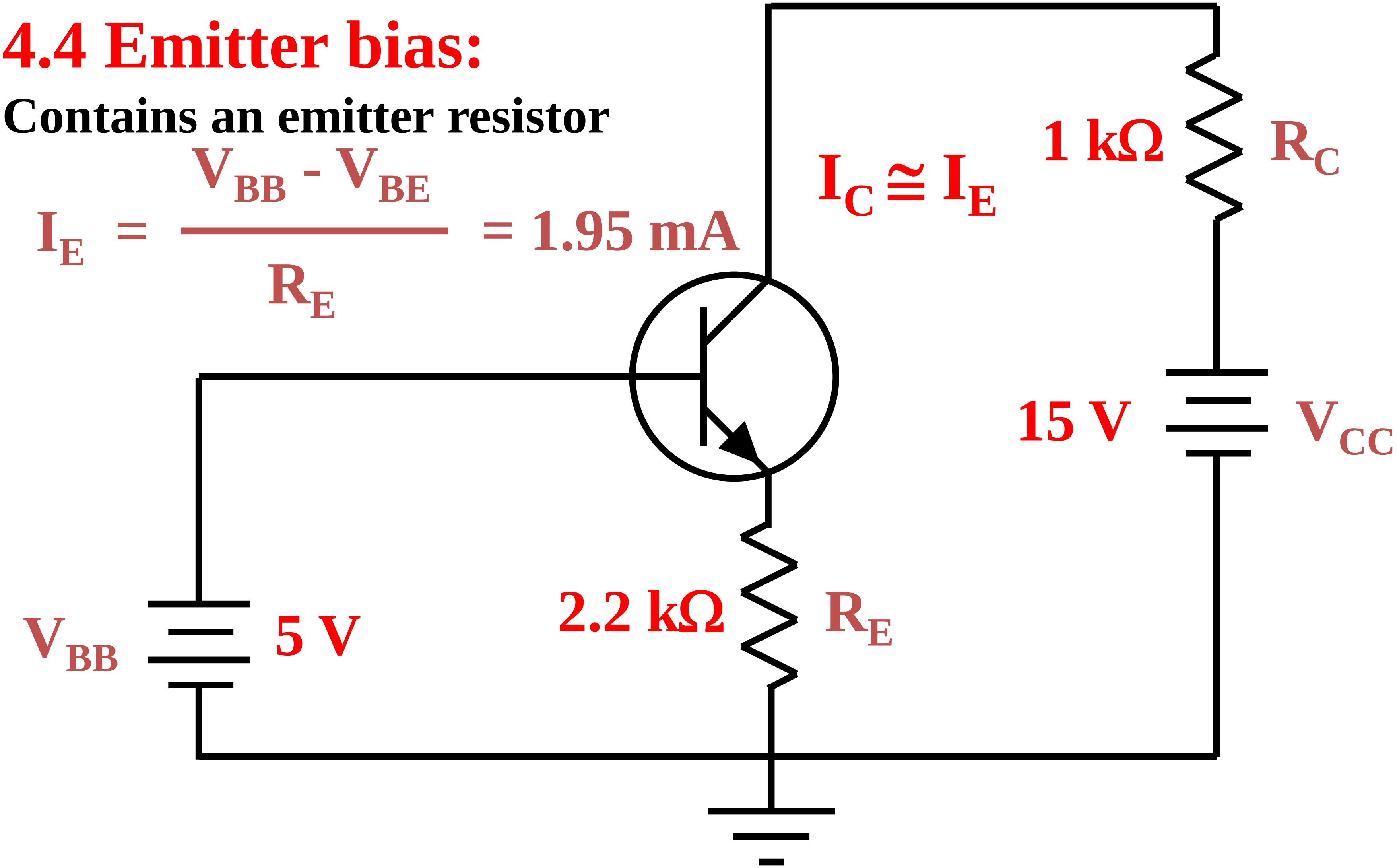
Find I_E, V_C, V_{CE}



4.4 Emitter bias:

Contains an emitter resistor

$$I_E = \frac{V_{BB} - V_{BE}}{R_E} = 1.95 \text{ mA}$$



$$V_C = 15 \text{ V} - (1.95 \text{ mA})(1 \text{ k}\Omega) = 13.1 \text{ V}$$

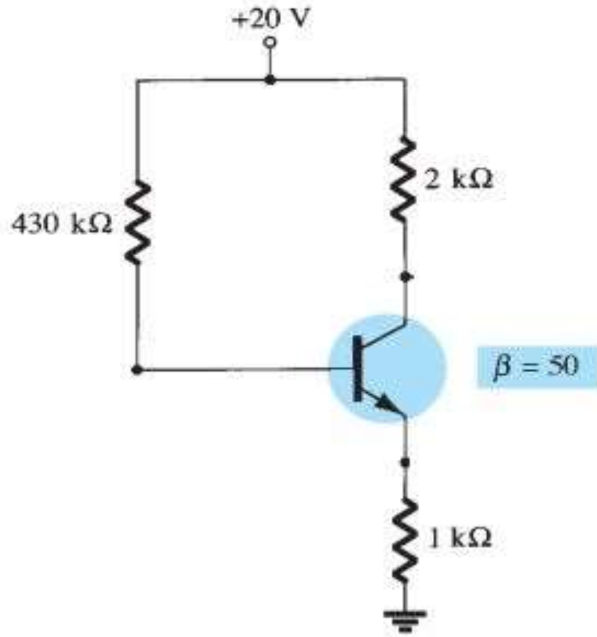
$$V_{CE} = 13.1 \text{ V} - 4.3 \text{ V} = 8.8 \text{ V}$$

BJT DC biasing

- First give appropriate directions of the three currents (I_E, I_B and I_C)
- Find α and β
- Apply KVL in the base-emitter loop. $V_{BE} = 0.7V$. Find I_B
- Find $I_C = \beta I_B$ and $I_E = I_B + I_C = (\beta + 1)I_B$ from I_B
- Apply KVL in the collector-emitter loop. Find V_{CE}
- Apply KVL in the base loop to find V_B
- $V_{BE} = 0.7V = V_B - V_E$. Find V_E
- $V_{CE} = V_C - V_E$. Find V_C
- Apply KVL in the emitter loop to find V_E

EXAMPLE 4.4 For the emitter-bias network of Fig. 4.23, determi

a. I_B.
b. I_C.
c. V_{CE}.
d. V_C.
e. V_E.
f. V_B.
g. V_{BC}.



EXAMPLE 4.4 For the emitter-bias network of Fig. 4.23, detern

a. I_B.
b. I_C.
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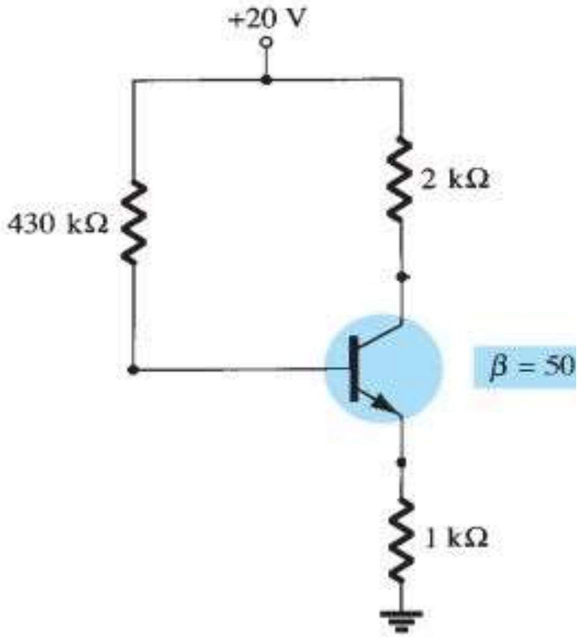

$$V_{CE} = V_{CC} - I_C(R_C + R_E)$$
$$= 20\text{ V} - (2.01\text{ mA})(2\text{ k}\Omega + 1\text{ k}\Omega) = 20\text{ V} - 6.03\text{ V}$$
$$= \mathbf{13.97\text{ V}}$$

Solution:

a. Eq. (4.17): $I_B = \dfrac{V_{CC} - V_{BE}}{R_B + (\beta + 1)R_E} = \dfrac{20\text{ V} - 0.7\text{ V}}{430\text{ k}\Omega + (51)(1\text{ k}\Omega)}$

$$= \frac{19.3\text{ V}}{481\text{ k}\Omega} = \mathbf{40.1\ \mu A}$$

b. $I_C = \beta I_B$

$$= (50)(40.1\ \mu\text{A})$$
$$\cong \mathbf{2.01\text{ mA}}$$

EXAMPLE 4.4 For the emitter-bias network of Fig. 4.23, determi

a. I_B.
b. I_C.
c. V_{CE}.
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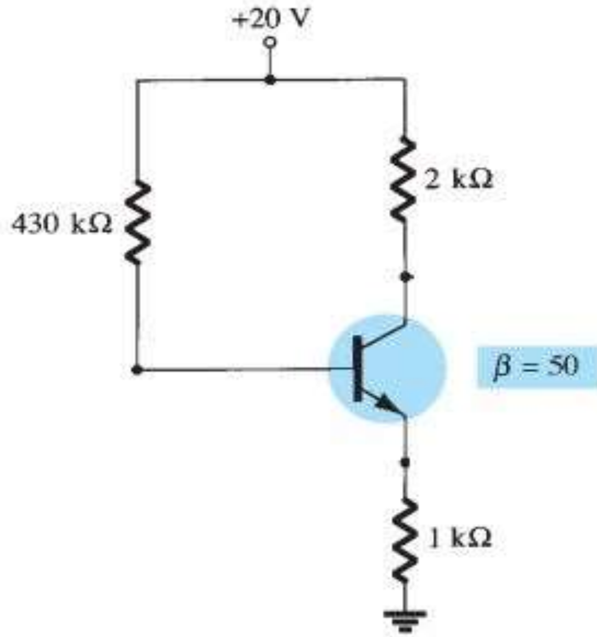


d. $V_C = V_{CC} - I_C R_C$
$= 20\text{ V} - (2.01\text{ mA})(2\text{ k}\Omega) = 20\text{ V} - 4.02\text{ V}$
$= \mathbf{15.98\text{ V}}$

e. $V_E = V_C - V_{CE}$
$= 15.98\text{ V} - 13.97\text{ V}$
$= \mathbf{2.01\text{ V}}$

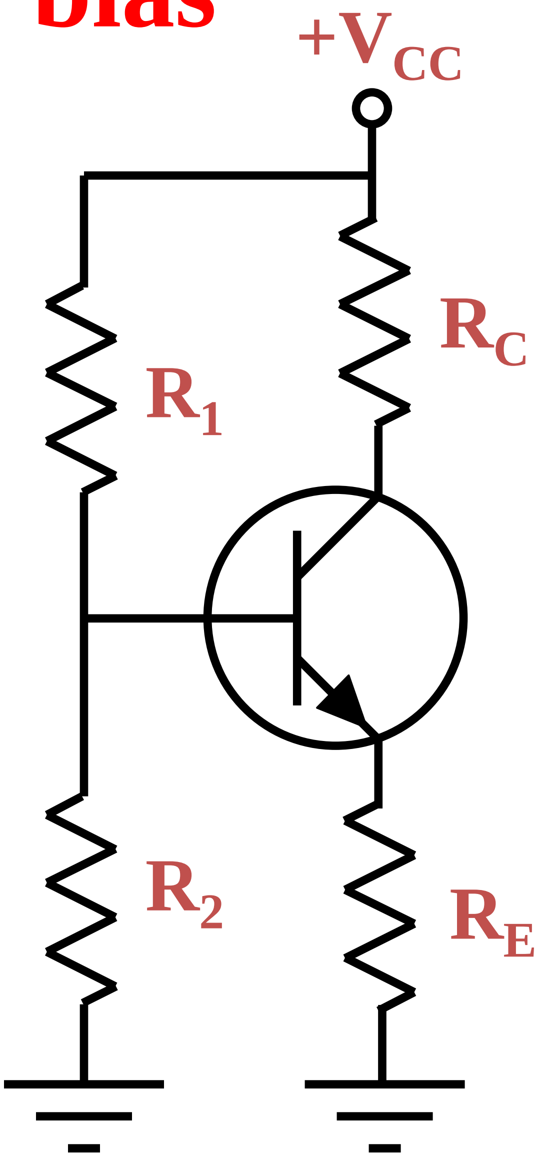
or $V_E = I_E R_E \cong I_C R_E$
$= (2.01\text{ mA})(1\text{ k}\Omega)$
$= \mathbf{2.01\text{ V}}$

f. $V_B = V_{BE} + V_E$
$= 0.7\text{ V} + 2.01\text{ V}$
$= \mathbf{2.71\text{ V}}$

g. $V_{BC} = V_B - V_C$
$= 2.71\text{ V} - 15.98\text{ V}$
$= \mathbf{-13.27\text{ V}}$ (reverse-biased as required)

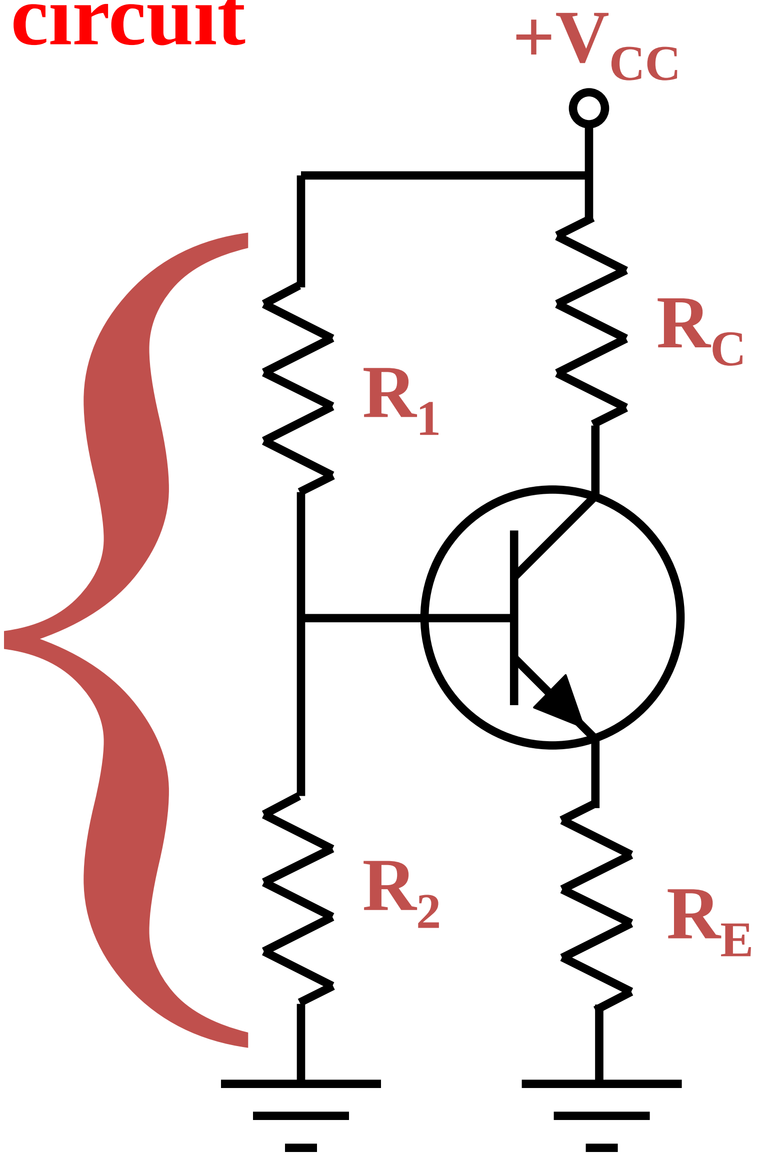
4.5 Voltage divider bias

- Base circuit contains a **voltage divider**
- Most widely used
- Known as **VDB**



Voltage divider bias circuit

R_1 and R_2 form a voltage divider



Divider analysis:

$$R_{th} = R_1 \parallel R_2$$

$$E_{th} = \frac{R_2}{R_1 + R_2} V_{CC}$$

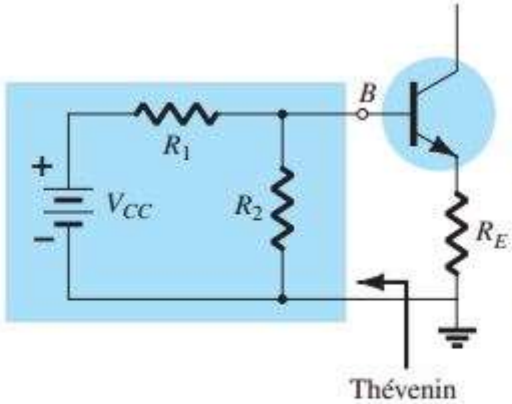


FIG. 4.31
Redrawing the input side of the network of Fig. 4.28.

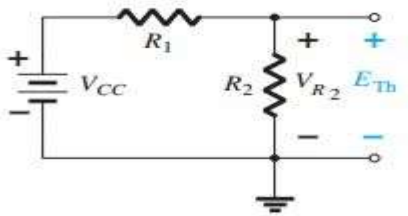


FIG. 4.33
Determining E_{Th}.

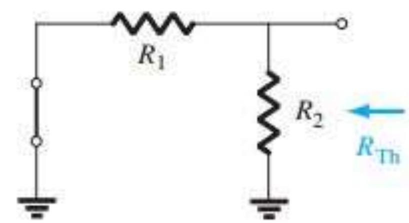


FIG. 4.32
Determining R_{Th}.

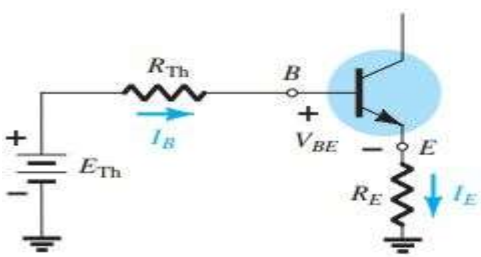
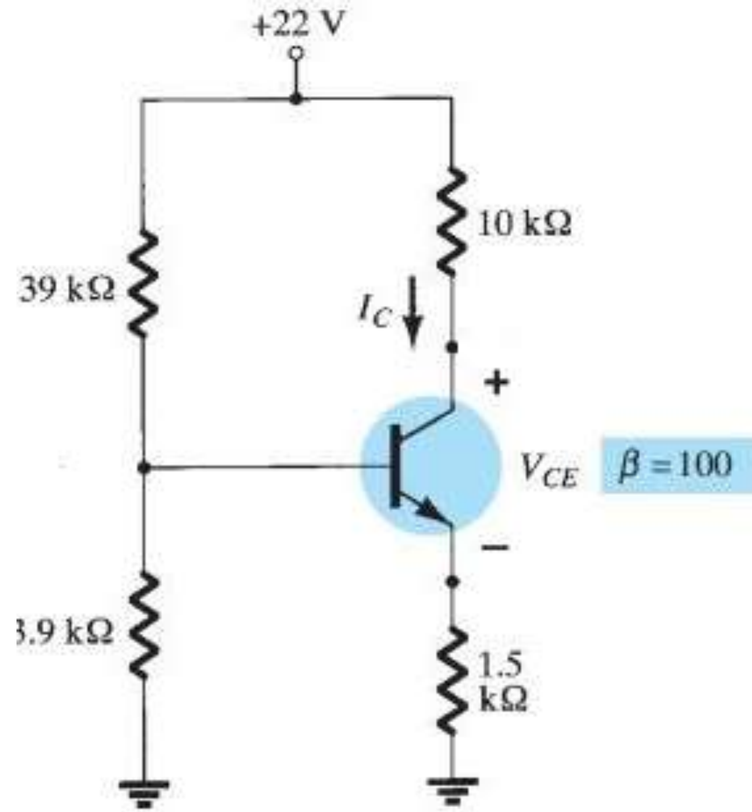


FIG. 4.34
Inserting the Thévenin equivalent circuit.

$$\boxed{I_B = \frac{E_{Th} - V_{BE}}{R_{Th} + (\beta + 1)R_E}}$$

EXAMPLE 4.8 Determine the dc bias voltage V_{CE} and the current I_C for the voltage-divider configuration of Fig. 4.35.



EXAMPLE 4.8 Determine the dc bias voltage V_{CE} and the current I_C for the voltage-divider configuration of Fig. 4.35.

Solution: Eq. (4.28): $R_{Th} = R_1 \| R_2$

$$= \frac{(39\,\text{k}\Omega)(3.9\,\text{k}\Omega)}{39\,\text{k}\Omega + 3.9\,\text{k}\Omega} = 3.55\,\text{k}\Omega$$

Eq. (4.29): $E_{Th} = \dfrac{R_2 V_{CC}}{R_1 + R_2}$

$$= \frac{(3.9\,\text{k}\Omega)(22\,\text{V})}{39\,\text{k}\Omega + 3.9\,\text{k}\Omega} = 2\,\text{V}$$

Eq. (4.30): $I_B = \dfrac{E_{Th} - V_{BE}}{R_{Th} + (\beta + 1)R_E}$

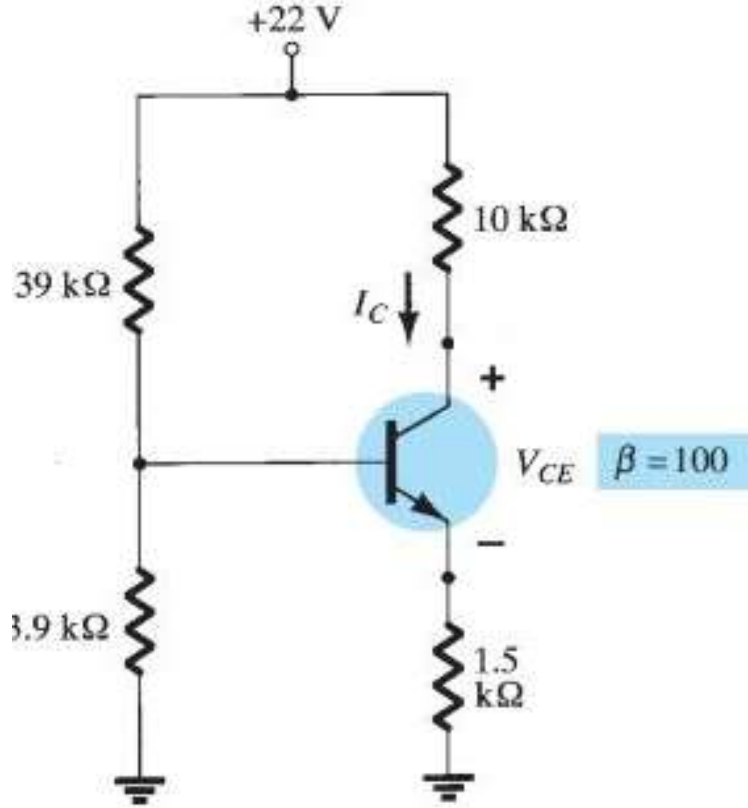
$$= \frac{2\,\text{V} - 0.7\,\text{V}}{3.55\,\text{k}\Omega + (101)(1.5\,\text{k}\Omega)} = \frac{1.3\,\text{V}}{3.55\,\text{k}\Omega + 151.5\,\text{k}\Omega}$$

$$= 8.38\,\mu\text{A}$$

$$I_C = \beta I_B$$

$$= (100)(8.38\,\mu\text{A})$$

$$= \mathbf{0.84\,mA}$$



$$V_{CE} = V_{CC} - I_C(R_C + R_E)$$

$$= 22\,\text{V} - (0.84\,\text{mA})(10\,\text{k}\Omega + 1.5\,\text{k}\Omega)$$

$$= 22\,\text{V} - 9.66\,\text{V}$$

$$= \mathbf{12.34\,V}$$

4.6 Collector-feedback bias

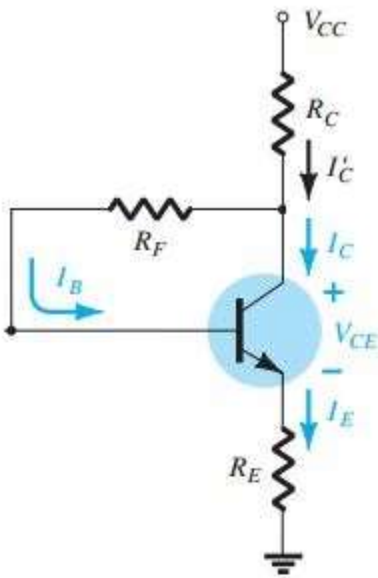


FIG. 4.38
DC bias circuit with voltage feedback.

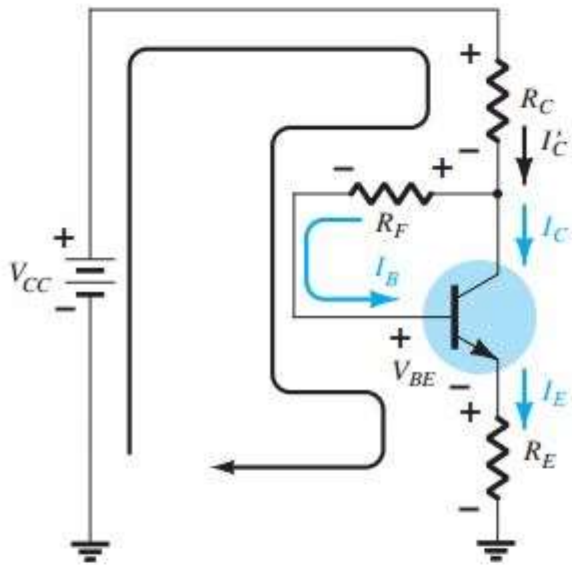


FIG. 4.39
Base–emitter loop for the network of Fig. 4.38.

Our text calls it DC Bias With Voltage Feedback

Current through $R_C = I_{R_C} = I_{C'}$

$$I_{C'} = I_C + I_{\mathrm{B}}$$

EXAMPLE 4.12 Determine the quiescent levels of I_{C_Q} and V_{CE_Q} for the network of Fig. 4.41.

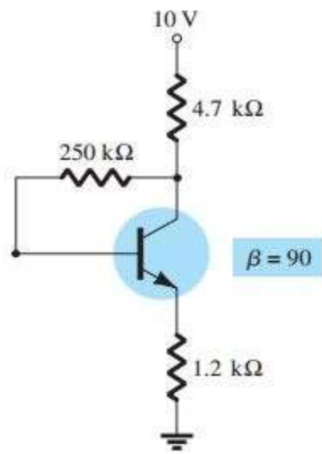
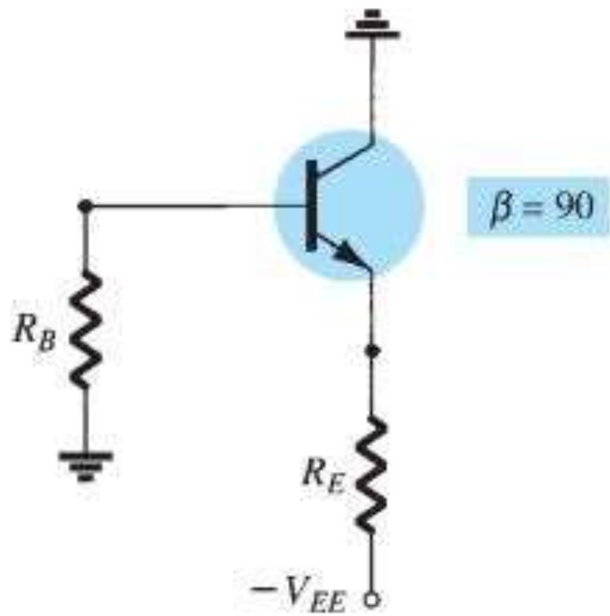


FIG. 4.41
Network for Example 4.12.

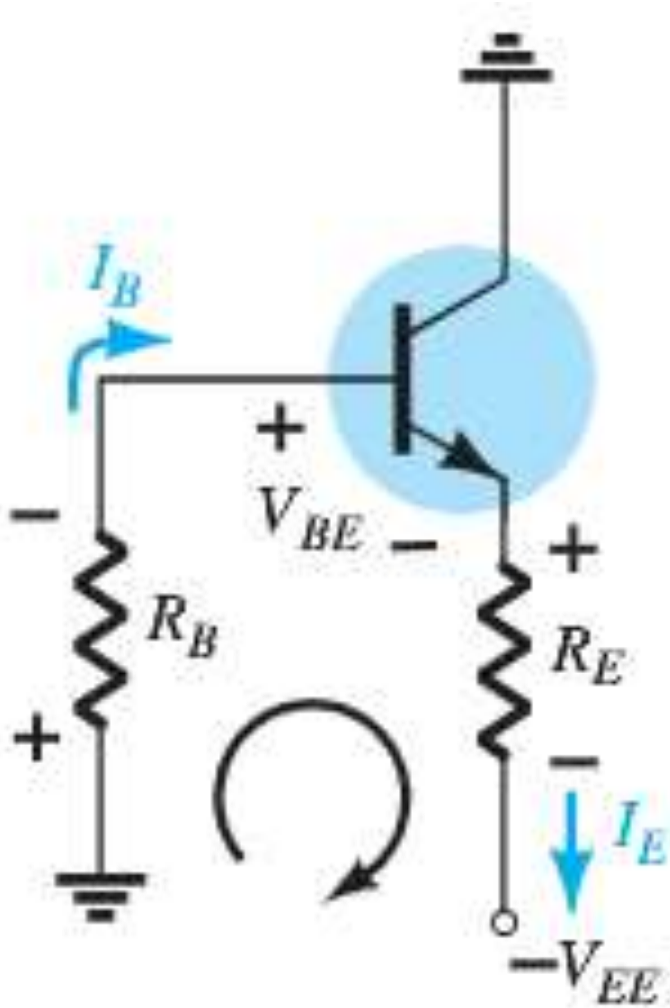
$$: \; I_B = \frac{V_{CC} - V_{BE}}{R_F + \beta(R_C + R_E)}$$
$$= \frac{10\text{ V} - 0.7\text{ V}}{250\text{ k}\Omega + (90)(4.7\text{ k}\Omega + 1.2\text{ k}\Omega)}$$
$$= \frac{9.3\text{ V}}{250\text{ k}\Omega + 531\text{ k}\Omega} = \frac{9.3\text{ V}}{781\text{ k}\Omega}$$
$$= 11.91\ \mu\text{A}$$
$$I_{C_Q} = \beta I_B = (90)(11.91\ \mu\text{A})$$
$$= \mathbf{1.07\ mA}$$
$$V_{CE_Q} = V_{CC} - I_C(R_C + R_E)$$
$$= 10\text{ V} - (1.07\text{ mA})(4.7\text{ k}\Omega + 1.2\text{ k}\Omega)$$
$$= 10\text{ V} - 6.31\text{ V}$$
$$= \mathbf{3.69\ V}$$

4.7 EMITTER-FOLLOWER CONFIGURATION



- The output is taken off the emitter terminal
- Also called Common Collector configuration

EMITTER-FOLLOWER DC ANALYSIS



$$-I_B R_B - V_{BE} - I_E R_E + V_{EE} = 0$$

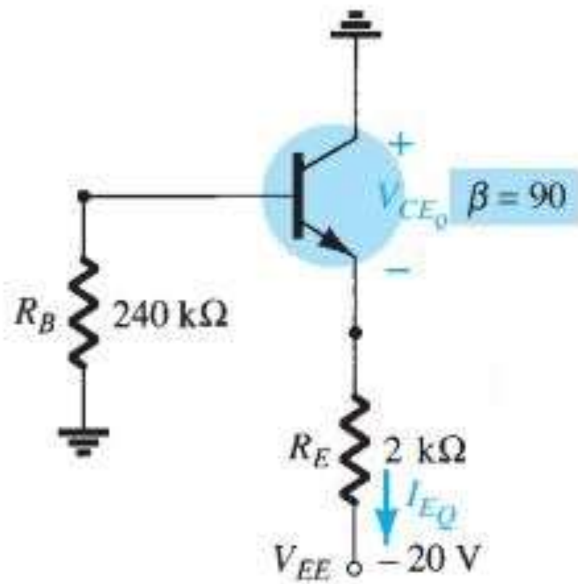
$$I_E = (\beta + 1) I_B$$

$$\boxed{I_B = \frac{V_{EE} - V_{BE}}{R_B + (\beta + 1) R_E}}$$

$$-V_{CE} - I_E R_E + V_{EE} = 0$$

$$\boxed{V_{CE} = V_{EE} - I_E R_E}$$

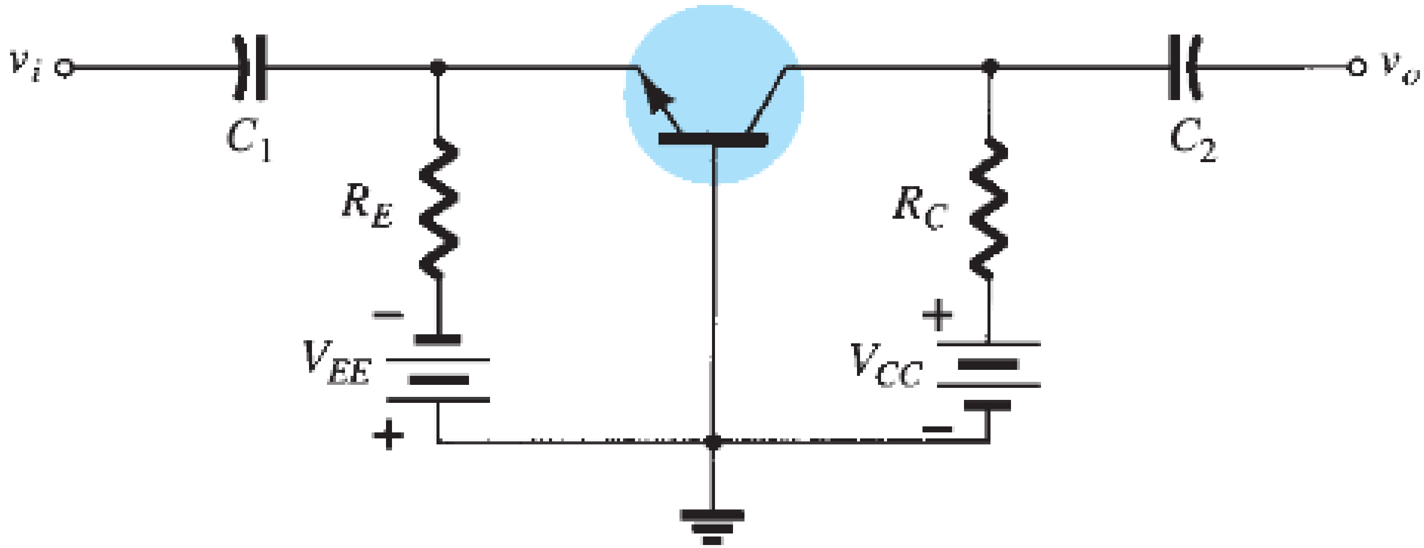
EXAMPLE 4.16 Determine V_{CE_Q} and I_{E_Q} for the network of Fig. 4.48.



$$I_B = \frac{V_{EE} - V_{BE}}{R_B + (\beta + 1)R_E}$$
$$= \frac{20\text{ V} - 0.7\text{ V}}{240\text{ k}\Omega + (90 + 1)2\text{ k}\Omega} = \frac{19.3\text{ V}}{240\text{ k}\Omega + 182\text{ k}\Omega}$$
$$= \frac{19.3\text{ V}}{422\text{ k}\Omega} = 45.73\ \mu\text{A}$$

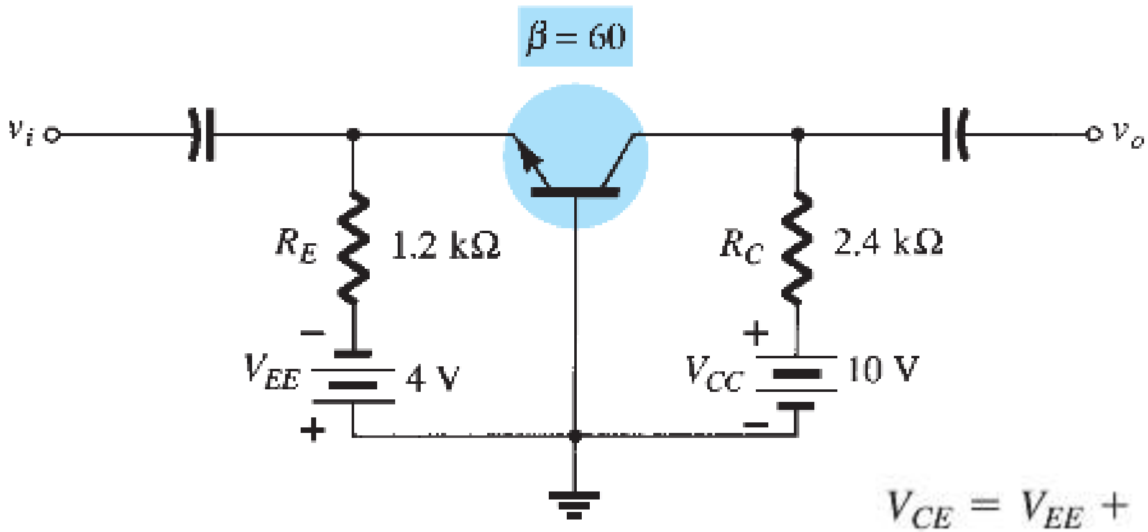
$$\begin{aligned}
V_{CE_Q} &= V_{EE} - I_E R_E \\
&= V_{EE} - (\beta + 1)I_B R_E \\
&= 20\text{ V} - (90 + 1)(45.73\ \mu\text{A})(2\text{ k}\Omega) \\
&= 20\text{ V} - 8.32\text{ V} \\
&= \mathbf{11.68\ V} \\
I_{E_Q} &= (\beta + 1)I_B = (91)(45.73\ \mu\text{A}) \\
&= 4.16\text{ mA}
\end{aligned}$$

4.8 COMMON-BASE CONFIGURATION



- The input signal is applied at the emitter terminal
- The base is at ground potential.
- The output signal is applied at the collector terminal

EXAMPLE 4.17 Determine the currents I_E and I_B and the voltages V_{CE} and V_{CB} for the common-base configuration of Fig. 4.52.



$$I_E = \frac{V_{EE} - V_{BE}}{R_E}$$

$$= \frac{4\text{ V} - 0.7\text{ V}}{1.2\text{ k}\Omega} = \mathbf{2.75\text{ mA}}$$

$$I_B = \frac{I_E}{\beta + 1} = \frac{2.75\text{ mA}}{60 + 1} = \frac{2.75\text{ mA}}{61}$$

$$= \mathbf{45.08\ \mu A}$$

$$\begin{aligned} V_{CE} &= V_{EE} + V_{CC} - I_E(R_C + R_E) \\ &= 4\text{ V} + 10\text{ V} - (2.75\text{ mA})(2.4\text{ k}\Omega + 1.2\text{ k}\Omega) \\ &= 14\text{ V} - (2.75\text{ mA})(3.6\text{ k}\Omega) \\ &= 14\text{ V} - 9.9\text{ V} \\ &= \mathbf{4.1\text{ V}} \end{aligned}$$

$$\begin{aligned} V_{CB} &= V_{CC} - I_C R_C = V_{CC} - \beta I_B R_C \\ &= 10\text{ V} - (60)(45.08\ \mu\text{A})(24\text{ k}\Omega) \\ &= 10\text{ V} - 6.49\text{ V} \\ &= \mathbf{3.51\text{ V}} \end{aligned}$$