MALVINO & BATES

Electronic PRINCIPLES

SEVENTH EDITION

Chapter 7

Transistor Fundamentals

Topics Covered in Chapter 7

- Variations in current gain
- The load line
- The operating point
- Recognizing saturation
- The transistor switch

Topics Covered in Chapter 7 (Continued)

- Emitter bias
- LED drivers
- The effect of small changes
- Troubleshooting
- More optoelectronic devices

Current gain

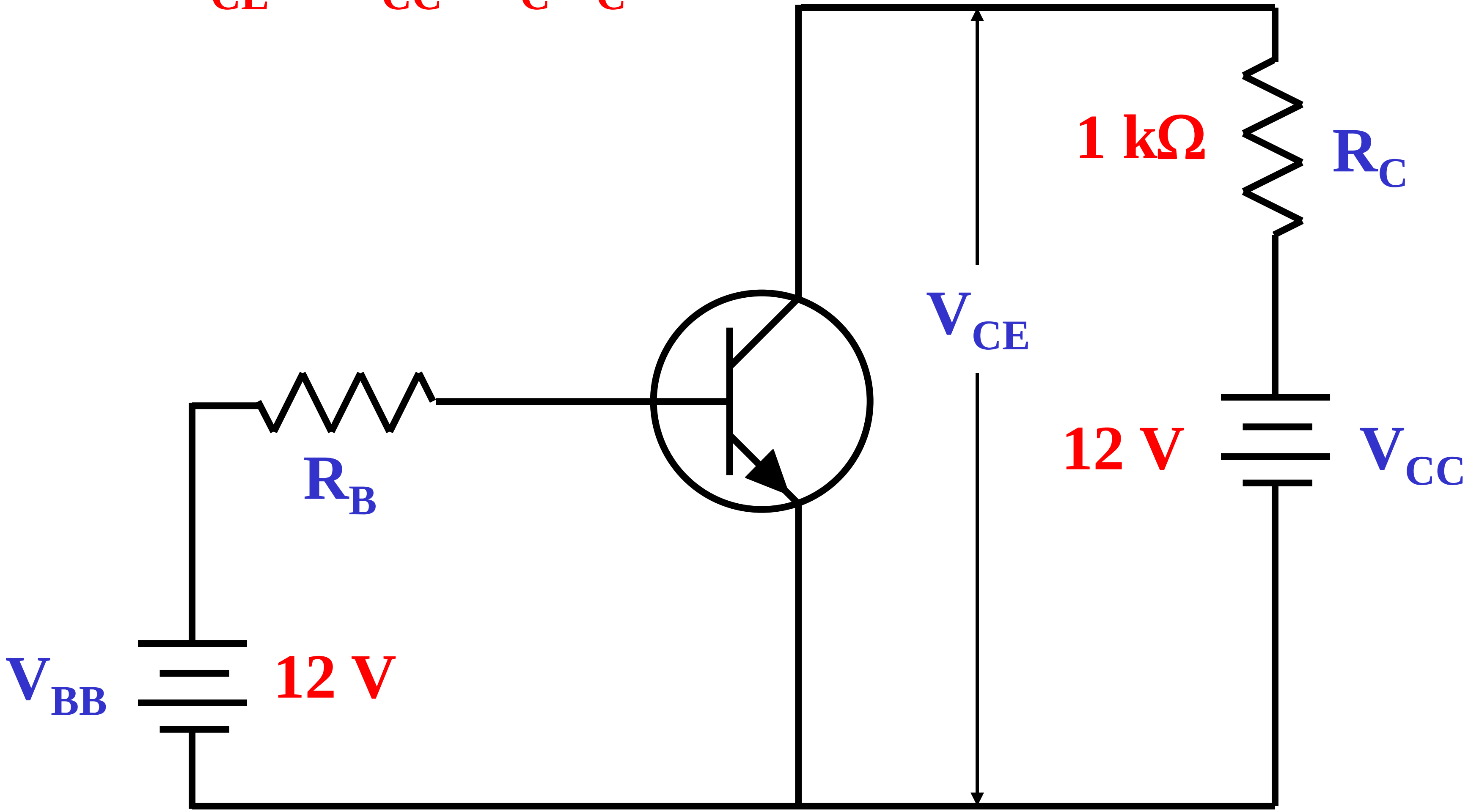
- **Depends on:**

✓ **Transistor**
✓ **Collector current**
✓ **Temperature**

Base bias

- **Setting up a fixed value of base current**
- **Base supply voltage (V_{BB}) divided by base resistor (R_B)**

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

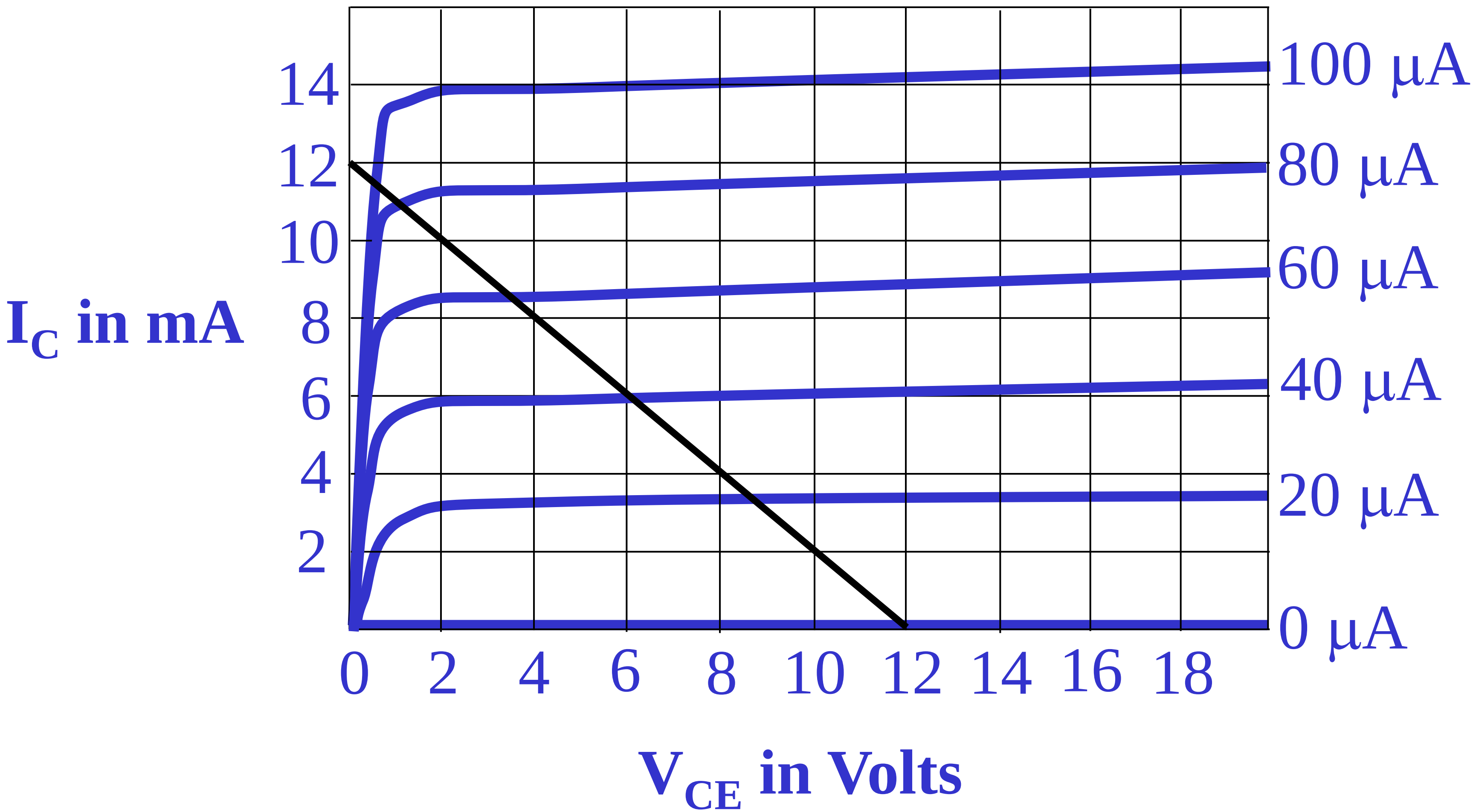


Load line

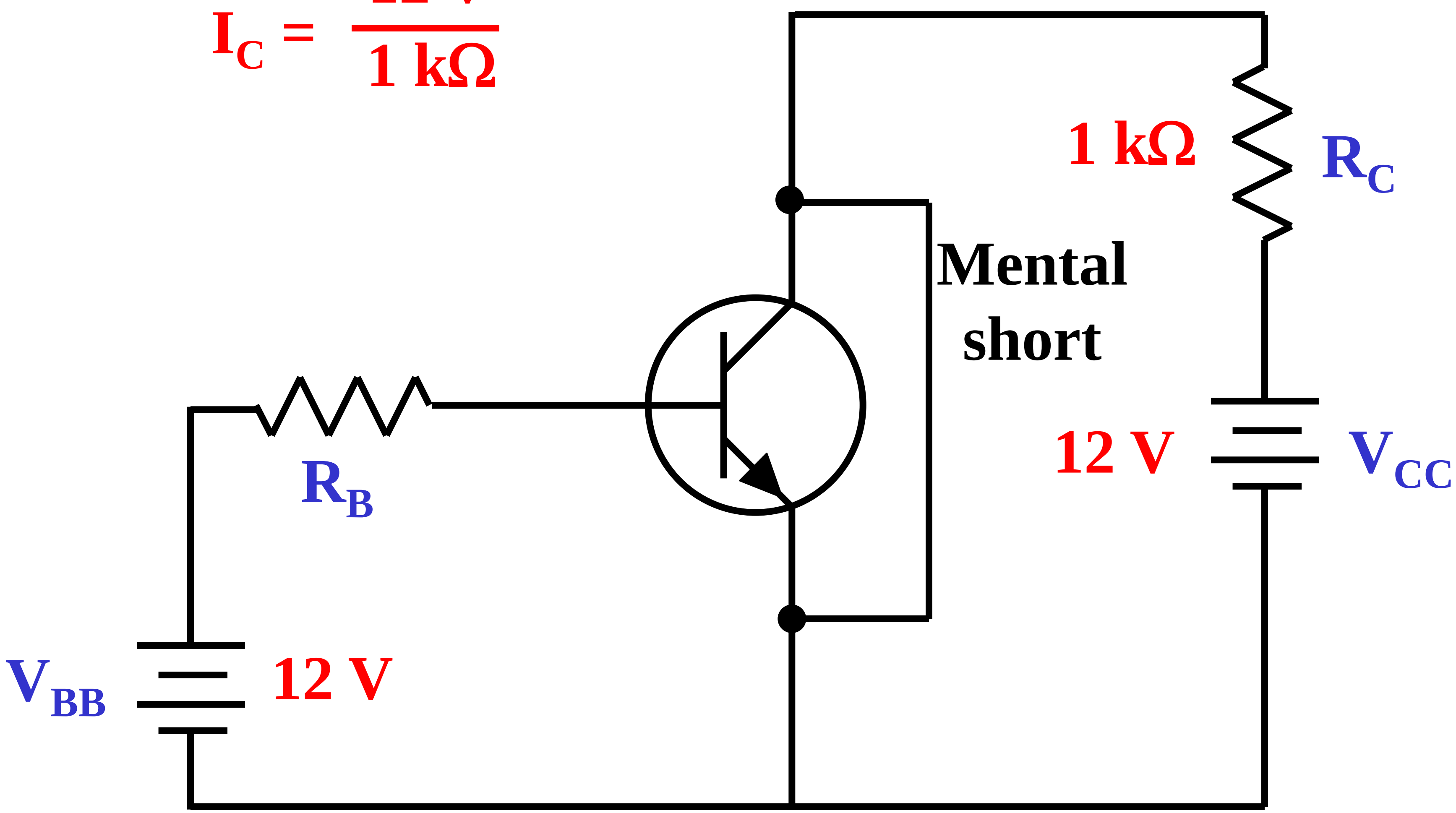
- Connects saturation current (I_{Csat}) to cutoff voltage ($V_{CEcutoff}$)
- A visual summary of all the possible transistor operating points

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

A graph of this equation produces a load line.

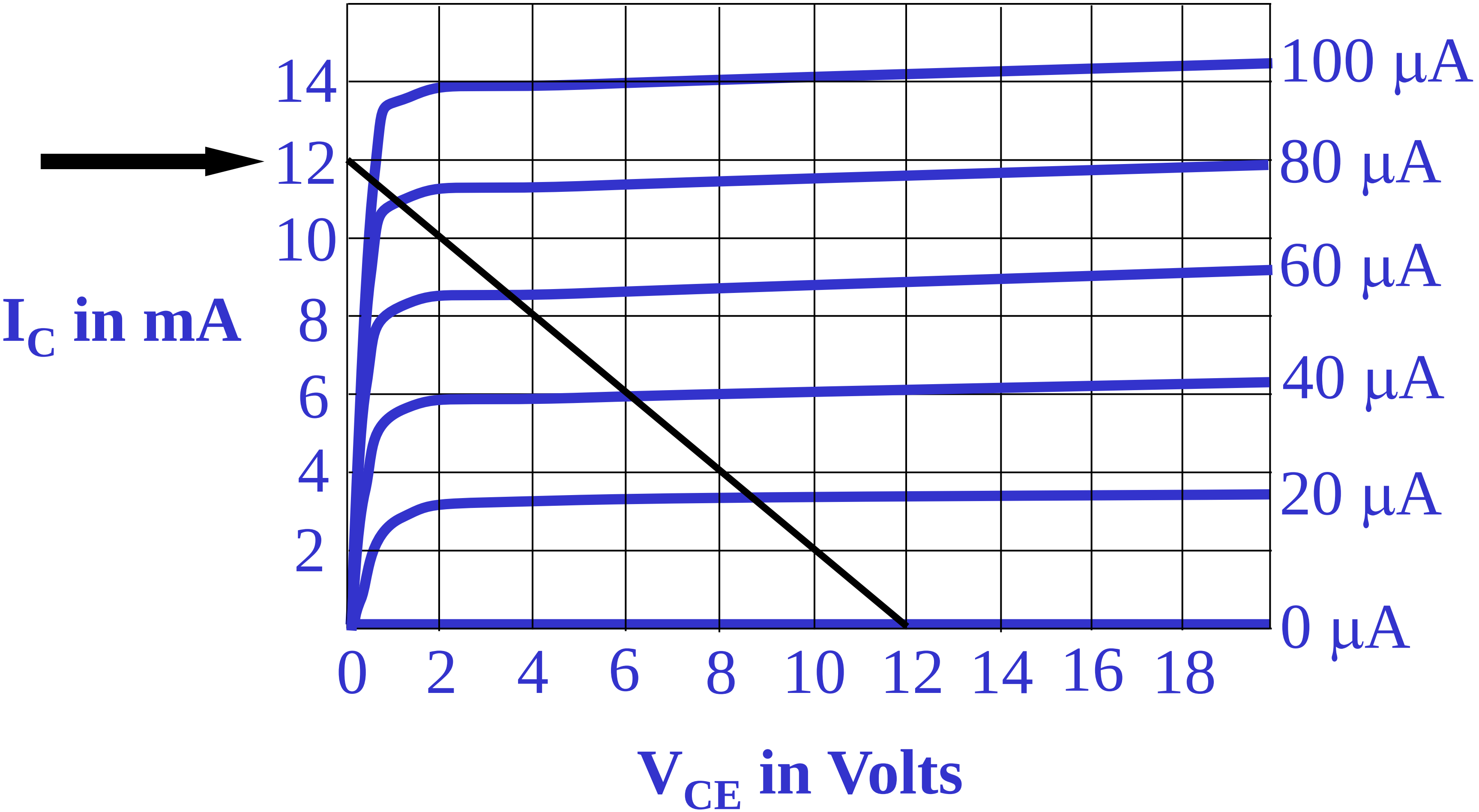


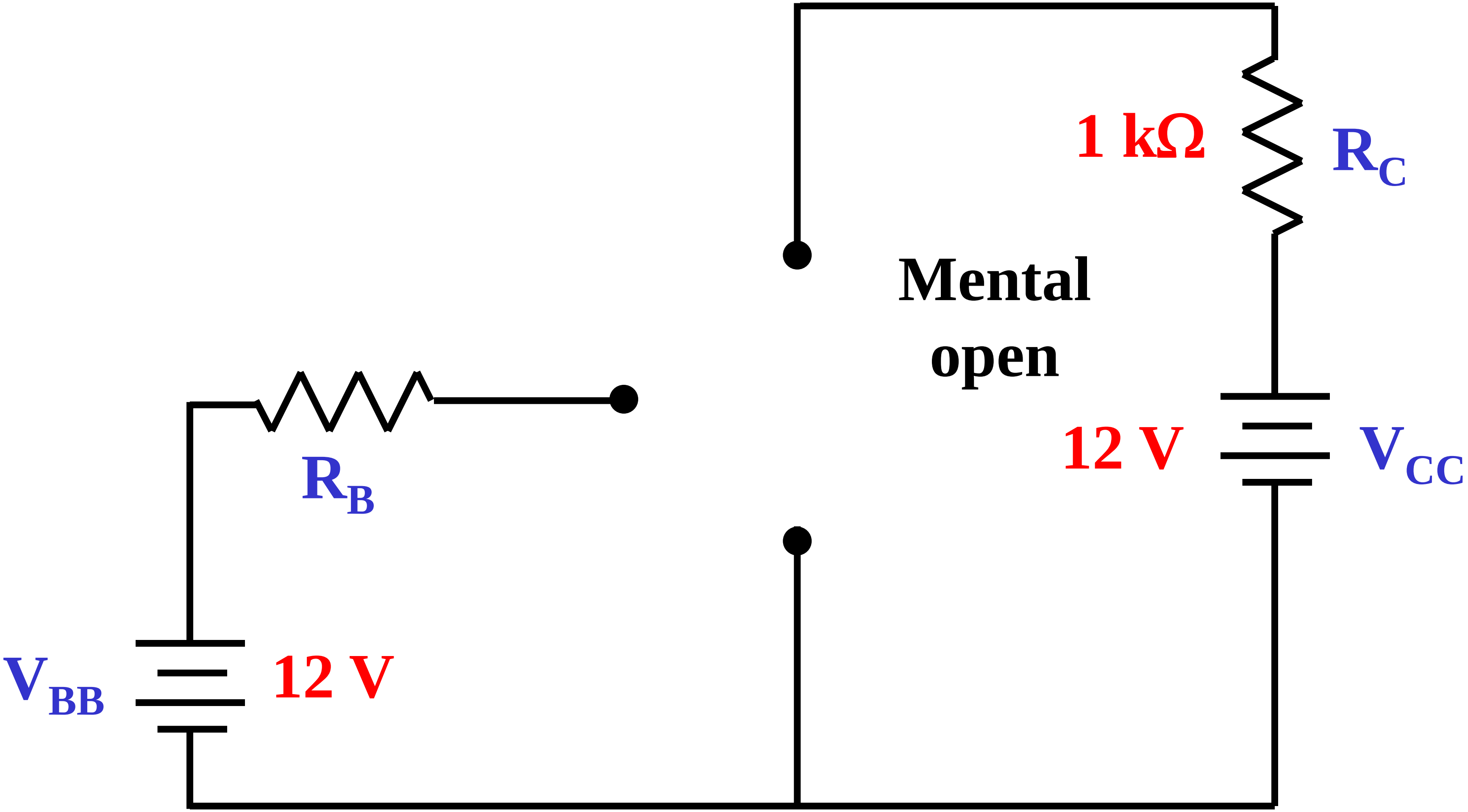
$$I_C = \frac{12\ V}{1\ k\Omega}$$



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

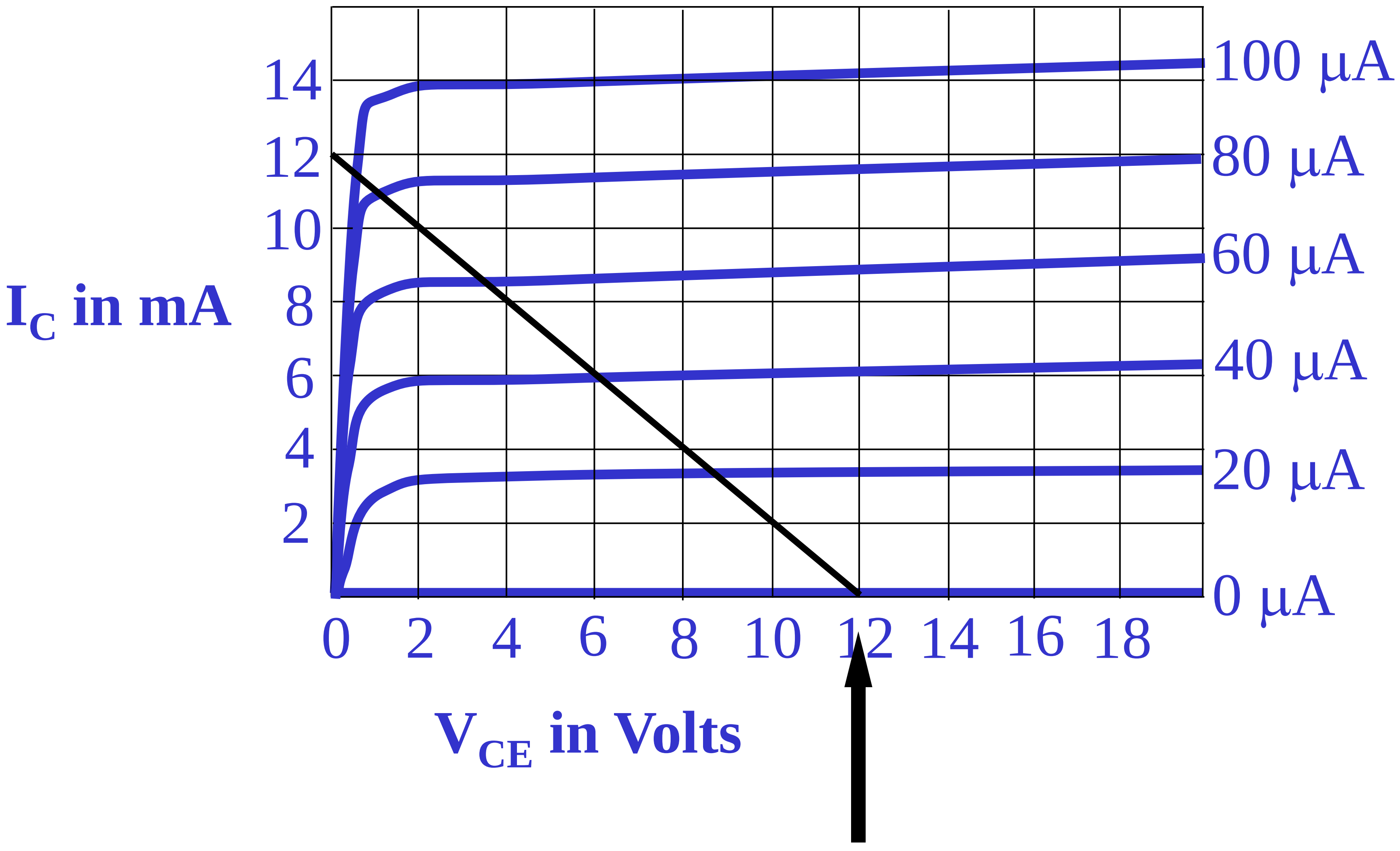
This is the Saturation (maximum) current.





1 kΩ
R_C
Mental
open
R_B
12 V
V_{CC}
V_{BB}
12 V

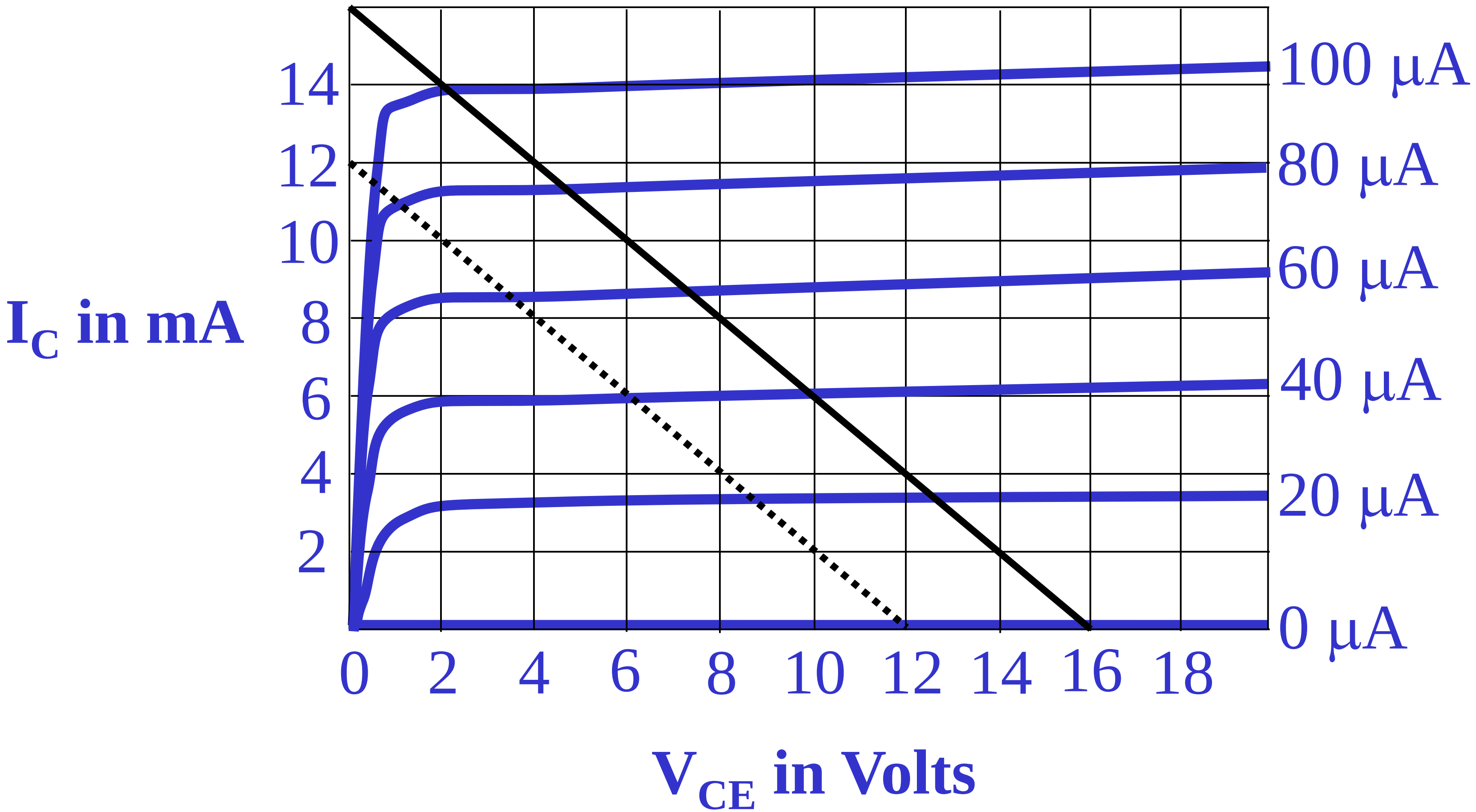
$V_{CE(cutoff)} = V_{CC}$



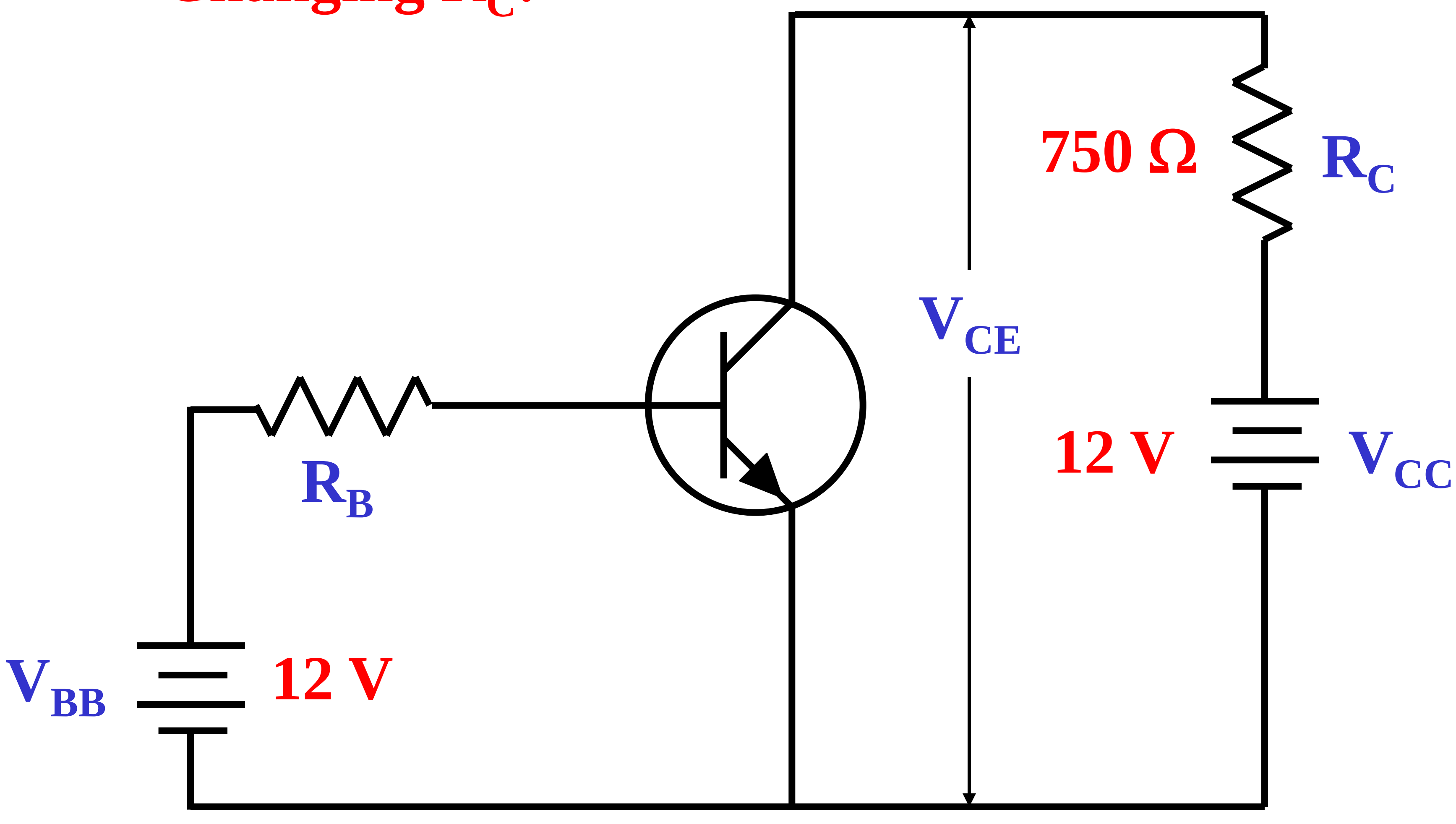
Load line slope

- Changing the collector supply voltage while keeping the same collector resistance produces two load lines
- These load lines will have the same slope but will have different saturation and cutoff values

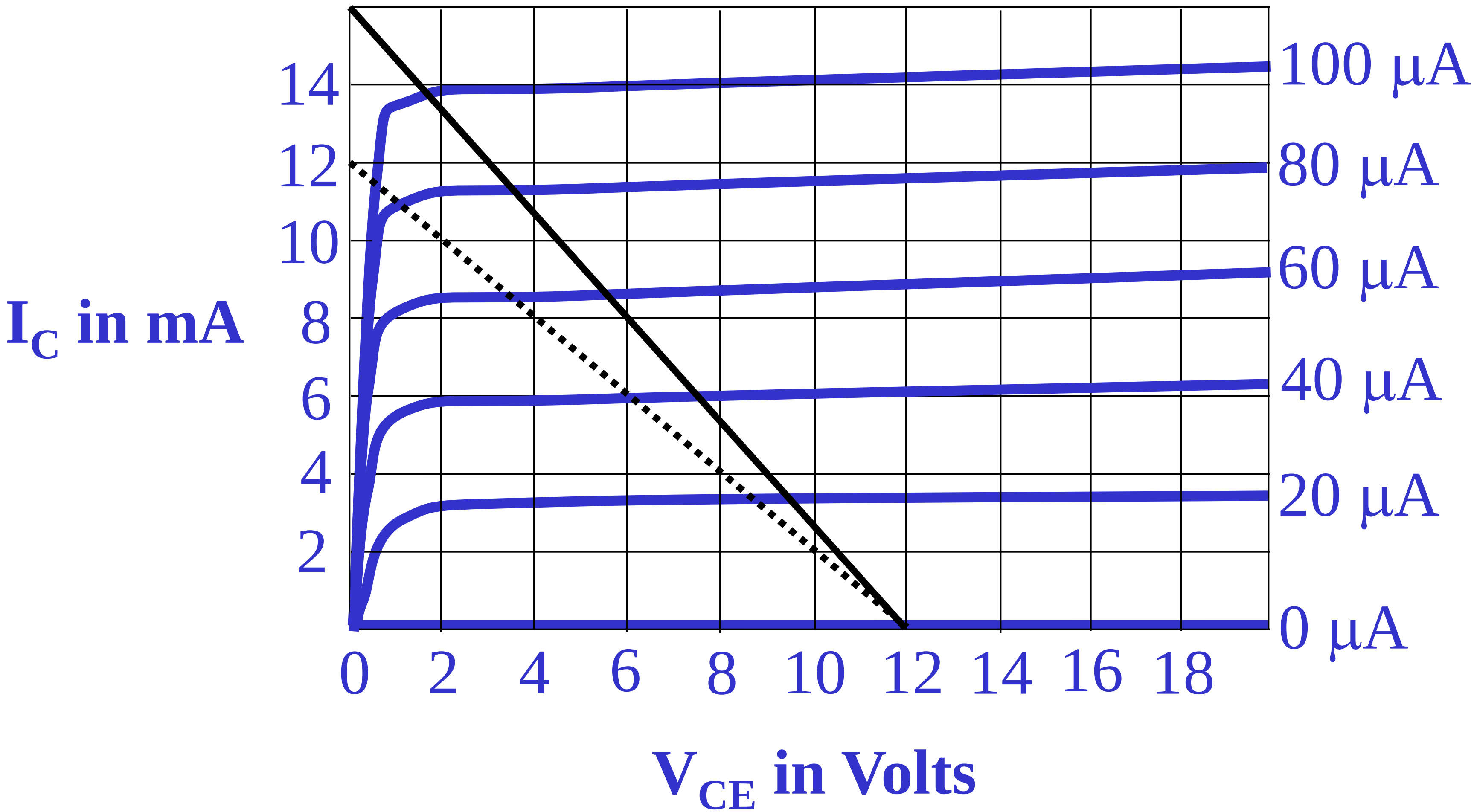
Same slope with new I_{Csat} and $V_{CEcutoff}$



Changing R_C:



A smaller R_C produces a higher value I_{Csat} and a steeper slope



Operating point

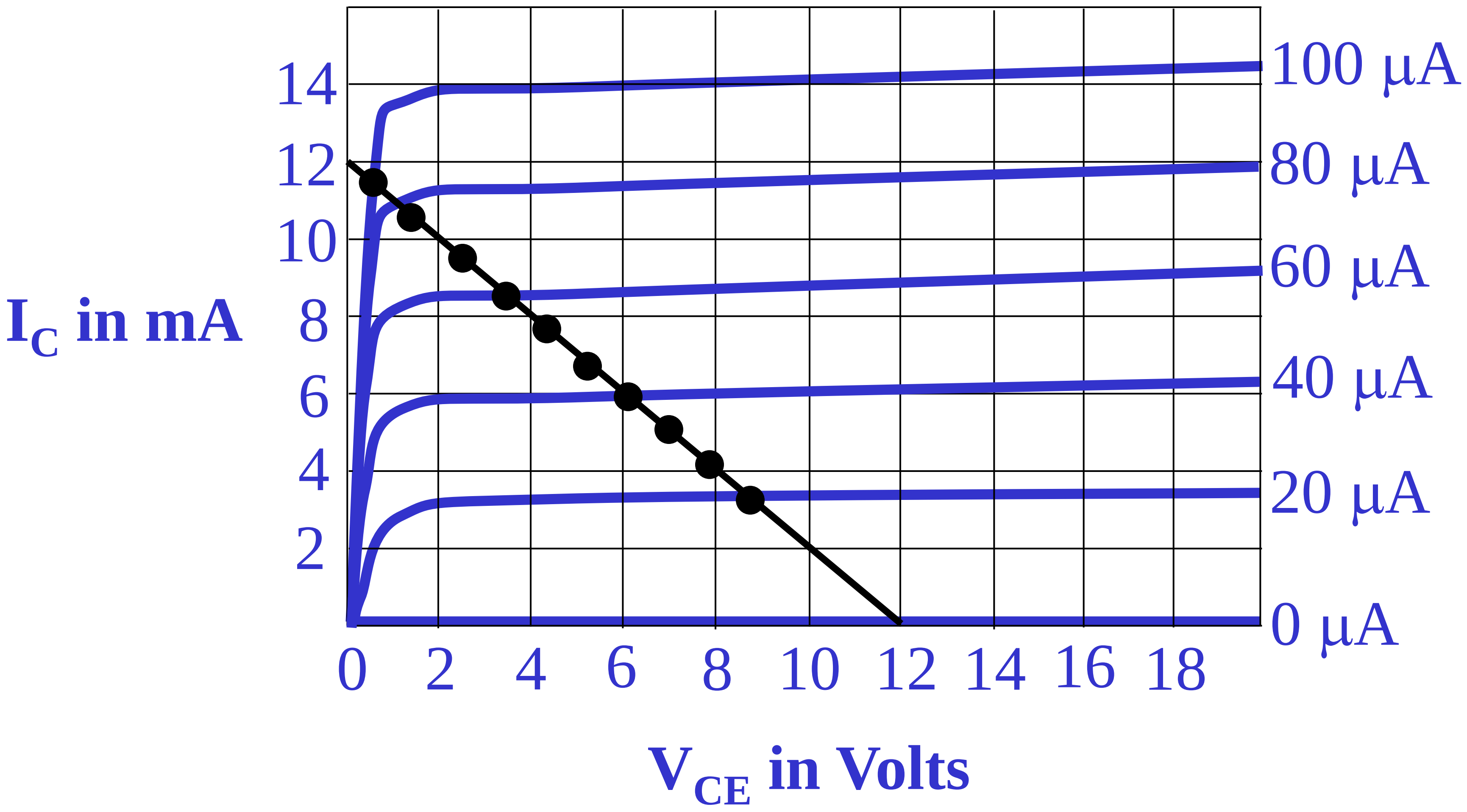
- **Determined by:**

✓ **Finding saturation current and cutoff voltage points**

✓ **Connecting points to produce a load line**

✓ **The operating (Q) point is established by the value of base current**

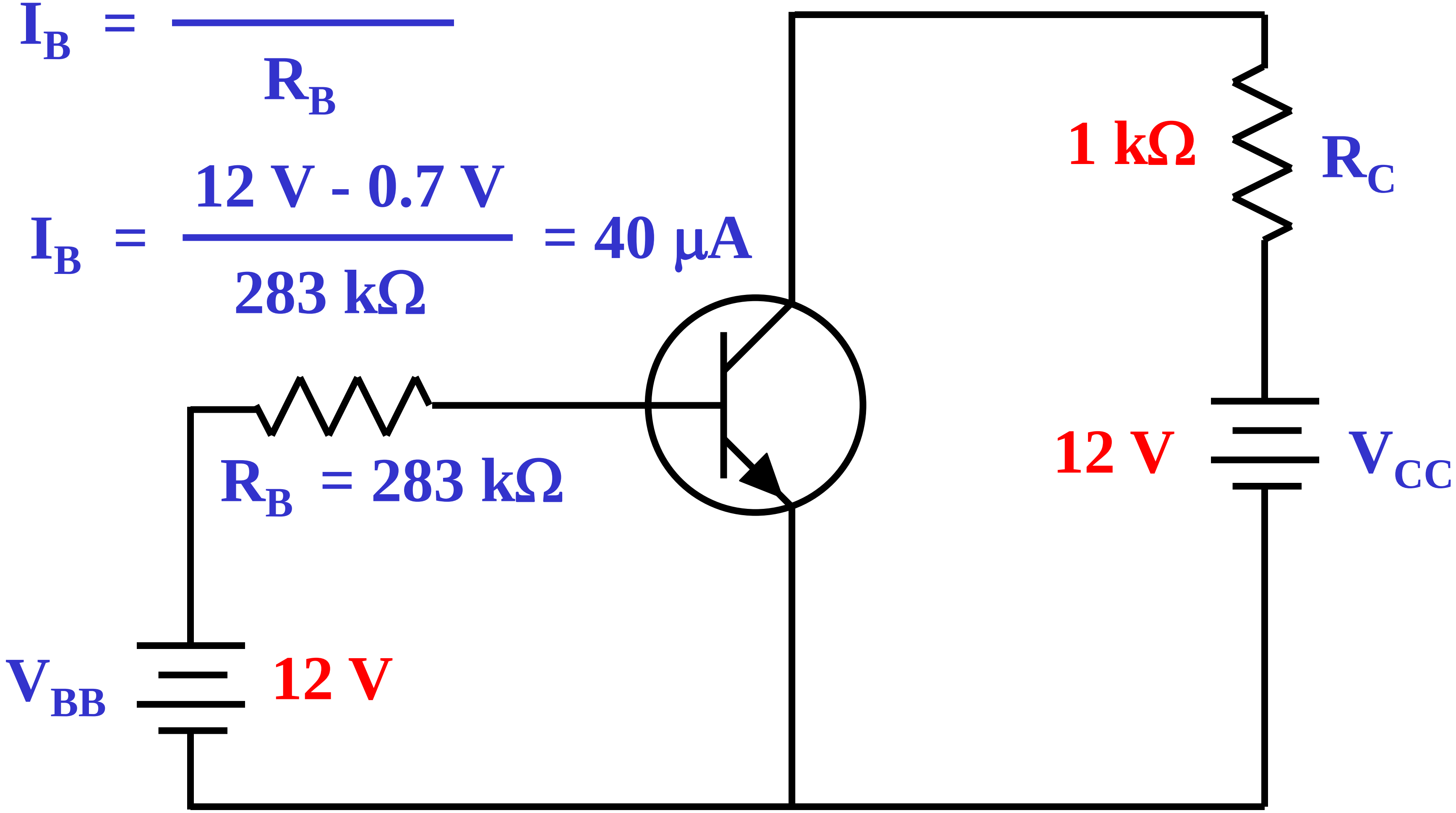
A circuit can operate at any point on the load line.



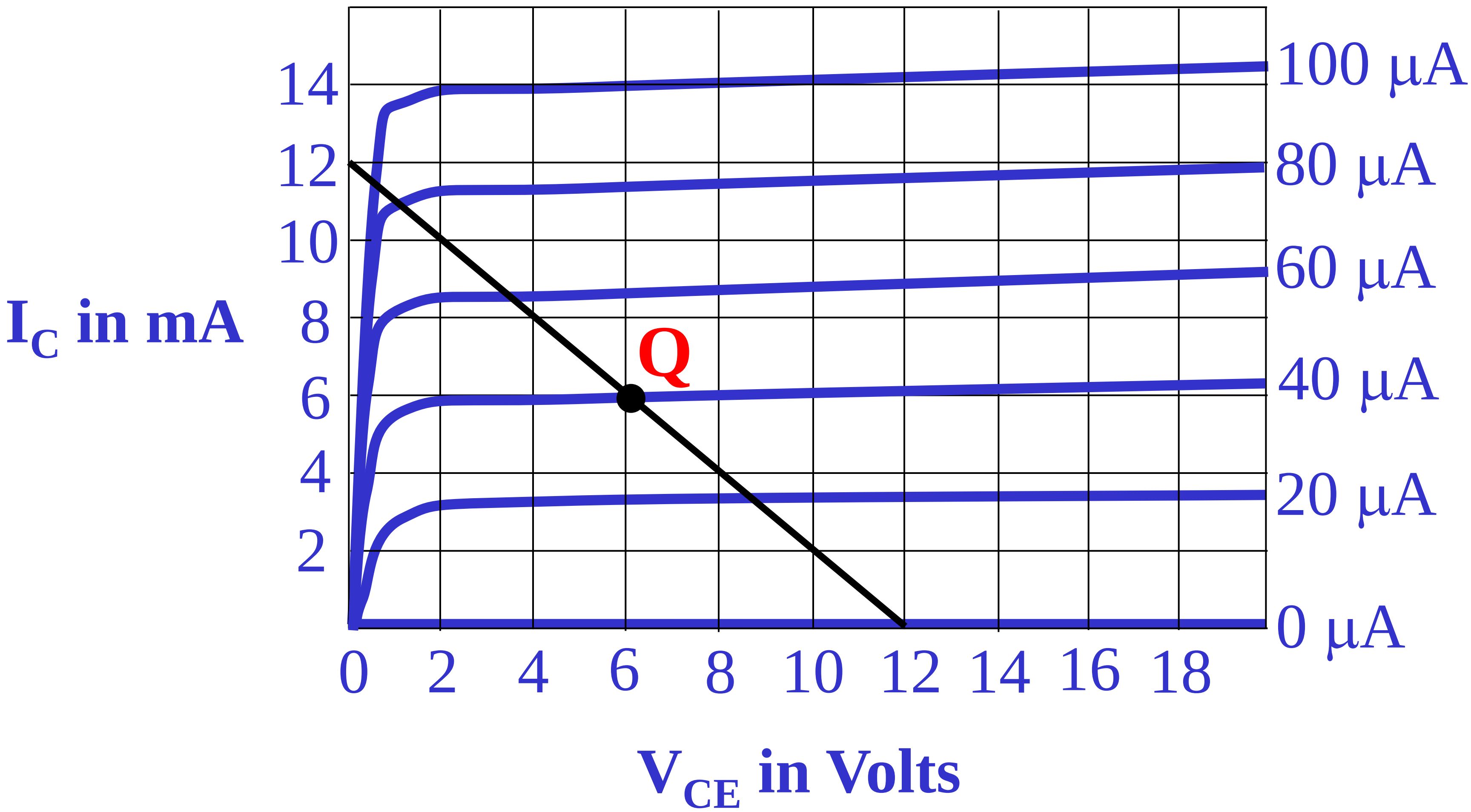
The operating point is determined by the base current.

$$I_B = \frac{V_{BB} - V_{BE}}{R_B}$$

$$I_B = \frac{12\ V - 0.7\ V}{283\ k\Omega} = 40\ \mu A$$

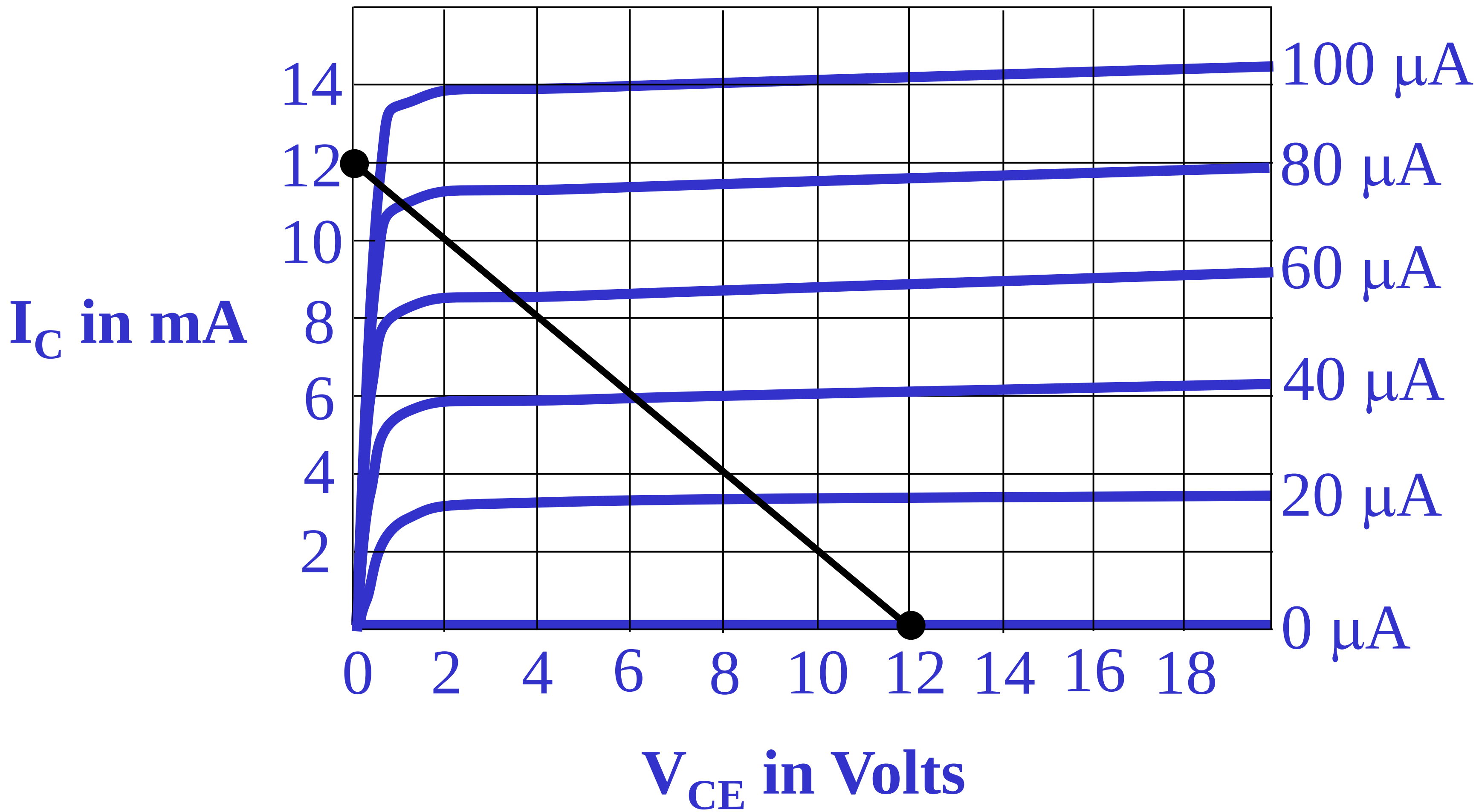


The operating point is called the Q or quiescent point.



This Q point is in the linear region.

Saturation and cutoff are non-linear operating points.



These Q points are used in switching applications.

Transistor circuits

- **Amplifying and switching**
- **Amplifying – Q point is in the active region**
- **Switching – Q point switches between saturation and cutoff**

Recognizing saturation

- Assume linear operation.
- Perform calculations for currents and voltages.
- An impossible result means the assumption is false.
- An impossible result indicates saturation.
- If the ratio of base to collector resistance is 10:1, the transistor is saturated.

Base bias

- The base current is established by V_{BB} and R_B.
- The collector current is β times larger in linear circuits.
- The transistor current gain will have a large effect on the operating point.
- Transistor current gain is unpredictable.

Transistor switch

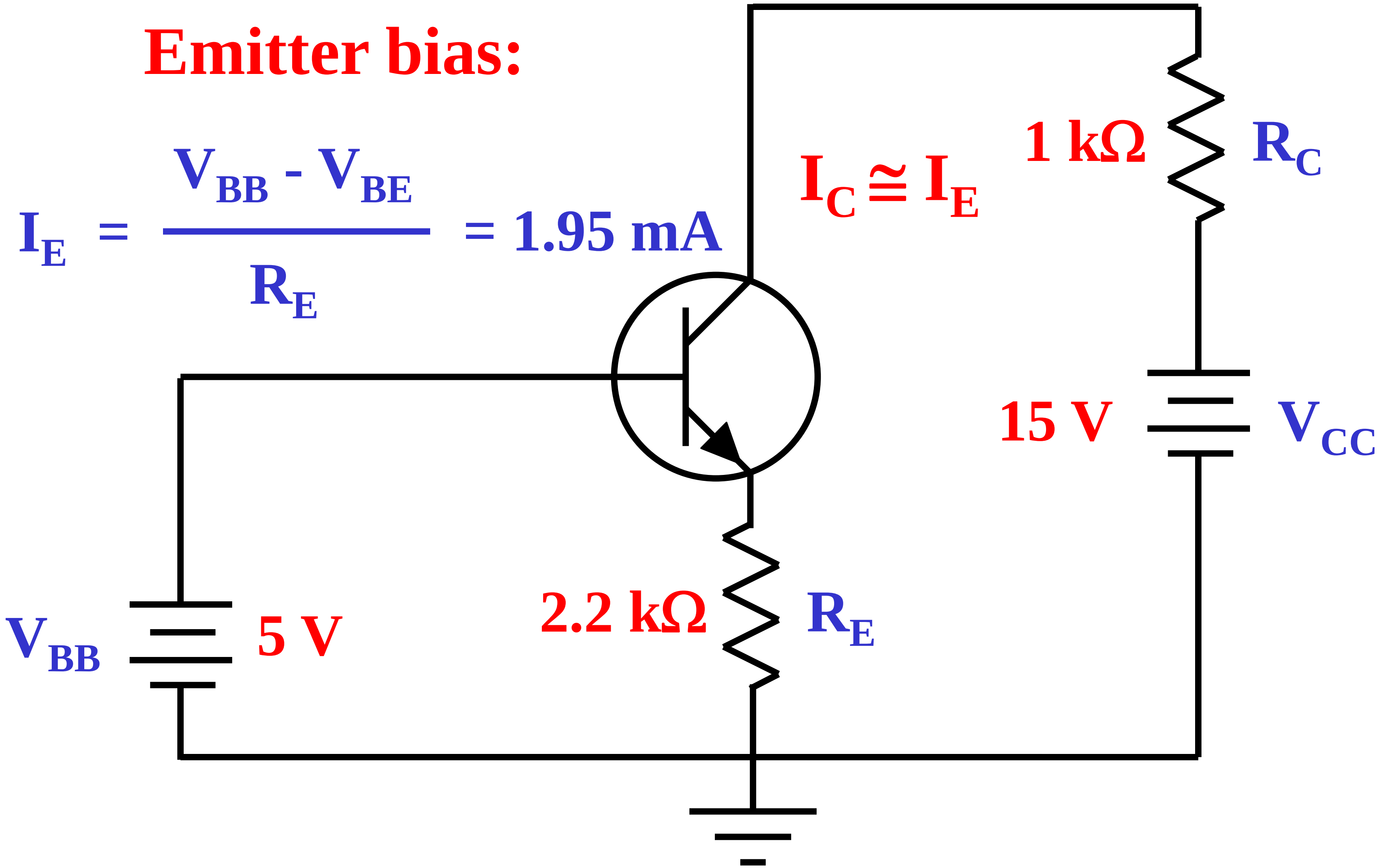
- Base bias is used
- The Q point switches between saturation and cutoff
- Switching circuits, also called two-state circuits, are used in digital applications

Emitter bias

- The bias resistor is moved from the base to emitter circuit
- Provides **Q points** that are immune to current gain changes
- Used for linear amplifiers

Emitter bias:

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



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

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

Comparing the bias methods

- **Base bias is subject to variations in transistor current gain.**
- **Base bias is subject to temperature effects.**
- **Emitter bias almost eliminates these effects.**
- **The transistor current gain is not required when solving circuits with emitter bias.**

Linear troubleshooting tips

- The difference between collector and emitter should be more than 1 V but less than V_{CC}.
- V_{BE} should be 0.6 to 0.7 V.
- V_{BE} can be 1 V or more in high-current circuits.
- Both open and shorted junctions are possible.

Troubleshooting a transistor

- Ohmmeter resistance tests
- DMM resistance or h_{FE} function tests
- In-circuit voltage measurements

Optoelectronic devices

- A phototransistor has current gain and is more sensitive than a photodiode
- Combined with an LED, a phototransistor provides a more sensitive optocoupler