# MALVINO & BATES

# Electronic PRINCIPLES

## SEVENTH EDITION

Chapter 6

# Bipolar Junction Transistors

# Topics Covered in Chapter 6

- **Unbiased transistor**
- **Biased transistor**
- **Transistor currents**
- **The CE connection**
- **The base curve**

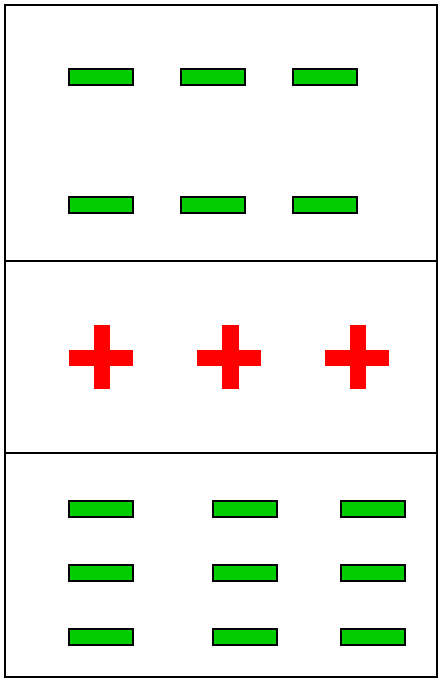
# Topics Covered in Chapter 6 (Continued)

- Collector curves
- Transistor approximations
- Reading data sheets
- Surface mount transistors
- Troubleshooting

# Unbiased transistor

- Three doped regions: emitter, base, and collector
- Two pn junctions: emitter-base and base-collector
- NPN or PNP
- Silicon or germanium

# The bipolar junction transistor has 3 doped regions.




**COLLECTOR (medium doping)**

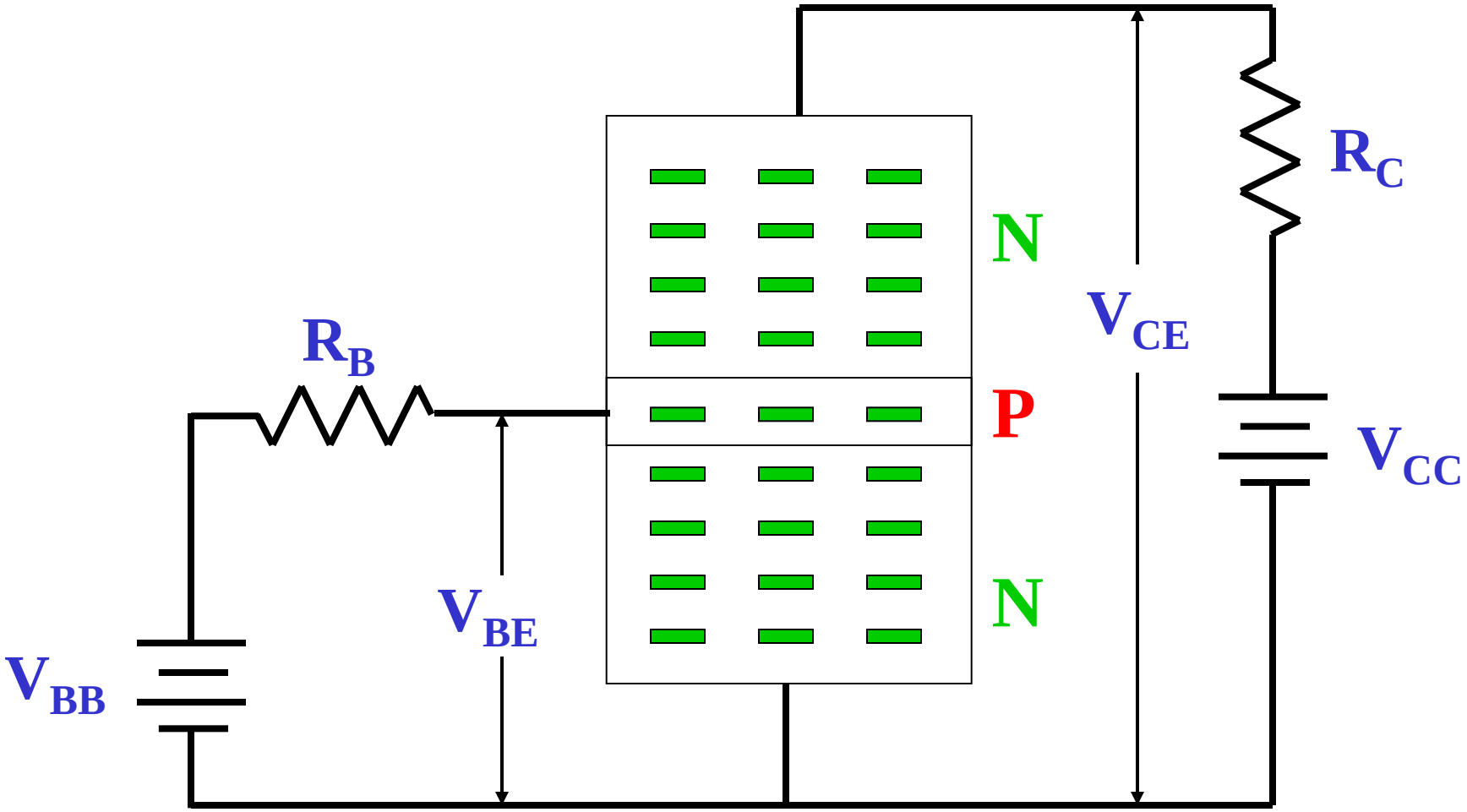
**BASE (light doping)**

**EMITTER (heavy doping)**

# Biased transistor

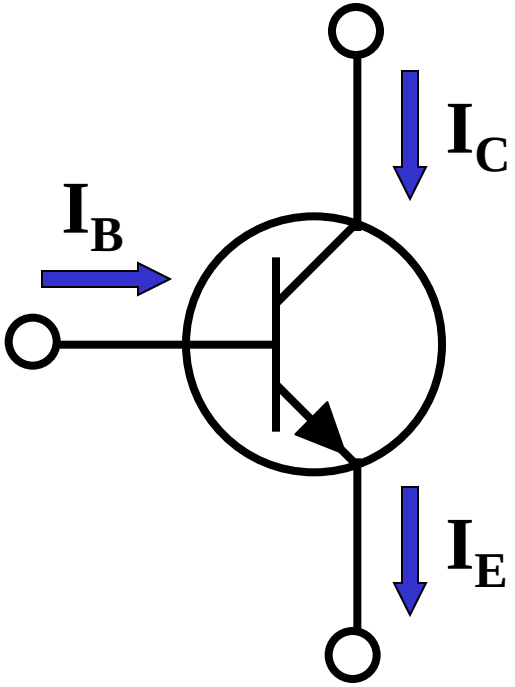
- Forward bias the emitter diode
- Reverse bias the collector diode

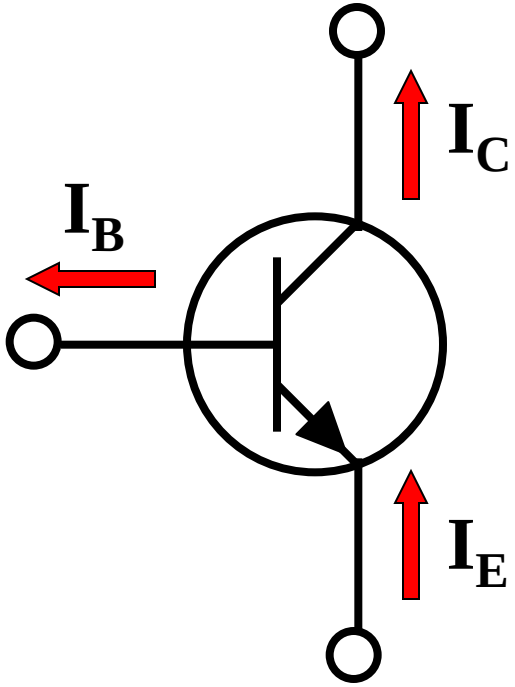
# In a properly biased NPN transistor, the emitter electrons diffuse into the base and then go on to the collector.



# Transistor currents

- The ratio of collector current to base current is current gain ($\beta_{dc}$ or $h_{FE}$)
- Current gain is typically 100 to 300




**Conventional flow**

**Electron flow**

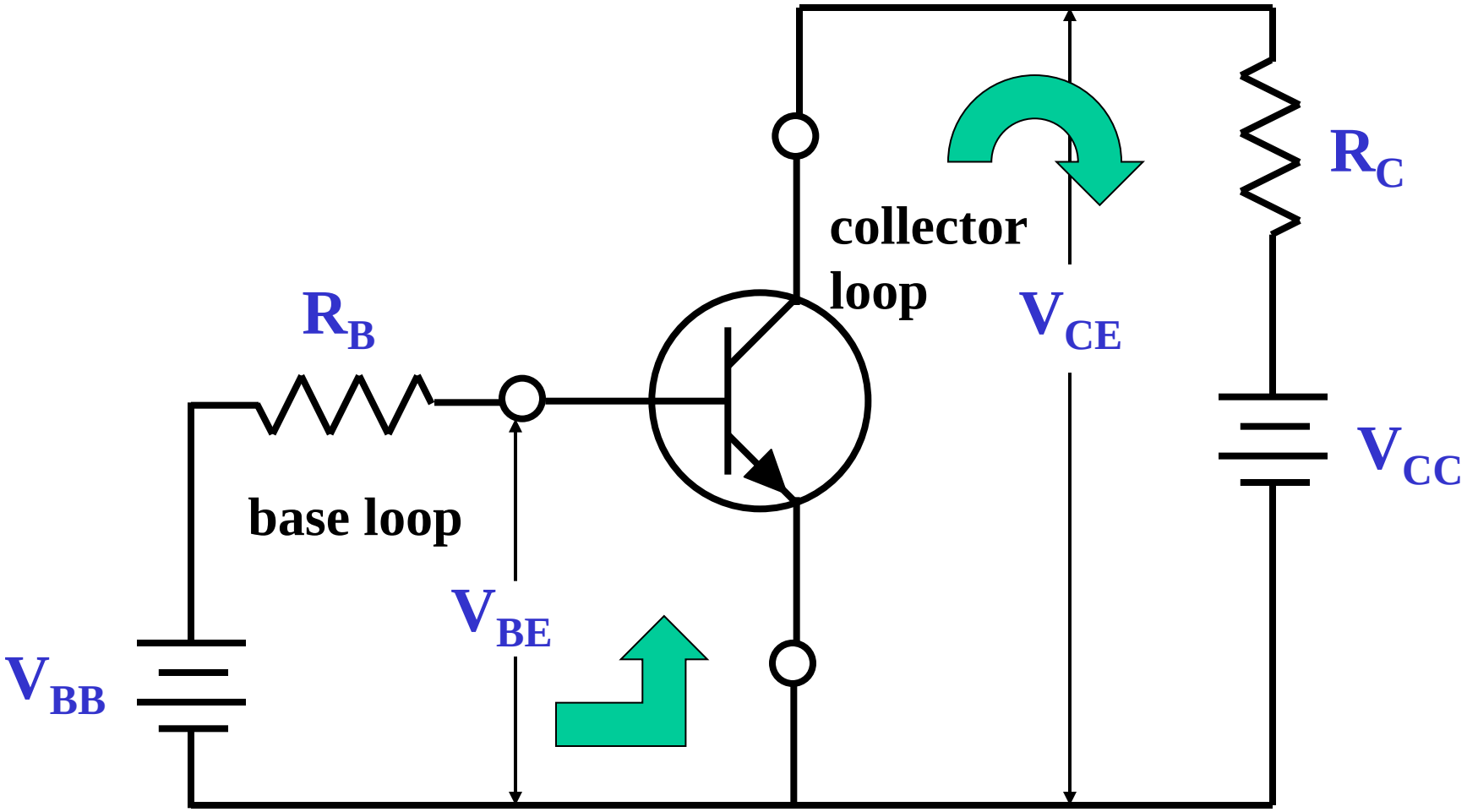
$$I_E = I_C + I_B \qquad I_C \cong I_E \qquad I_B << I_C$$

$$\alpha_{dc} = \frac{I_C}{I_E} \qquad \beta_{dc} = \frac{I_C}{I_B}$$

# The CE connection

- The emitter is grounded or common
- The base-emitter acts like a diode
- The base-collector acts like a current source that is equal to $\beta_{dc}$ times the base current

# The common emitter connection has two loops: the base loop and the collector loop.



# Subscript notation

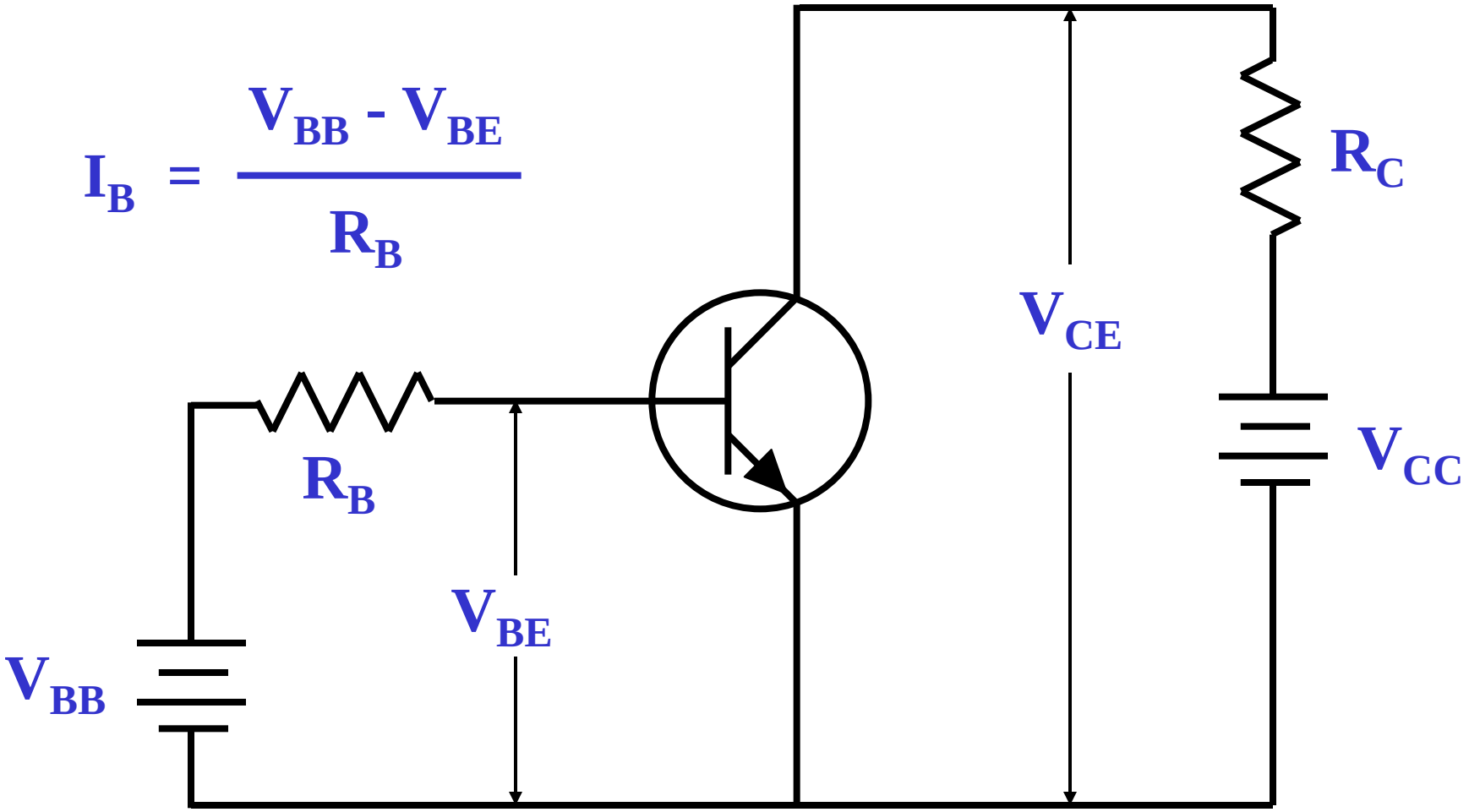
- When the subscripts are the same, the voltage represents a source ($V_{CC}$).
- When the subscripts are different, the voltage is between two points ($V_{CE}$).
- Single subscripts are used for node voltages with ground serving as the reference ($V_C$).

# Base curve

- Graph similar to that of a diode
- Diode approximations are used for analysis (typically - ideal or second)

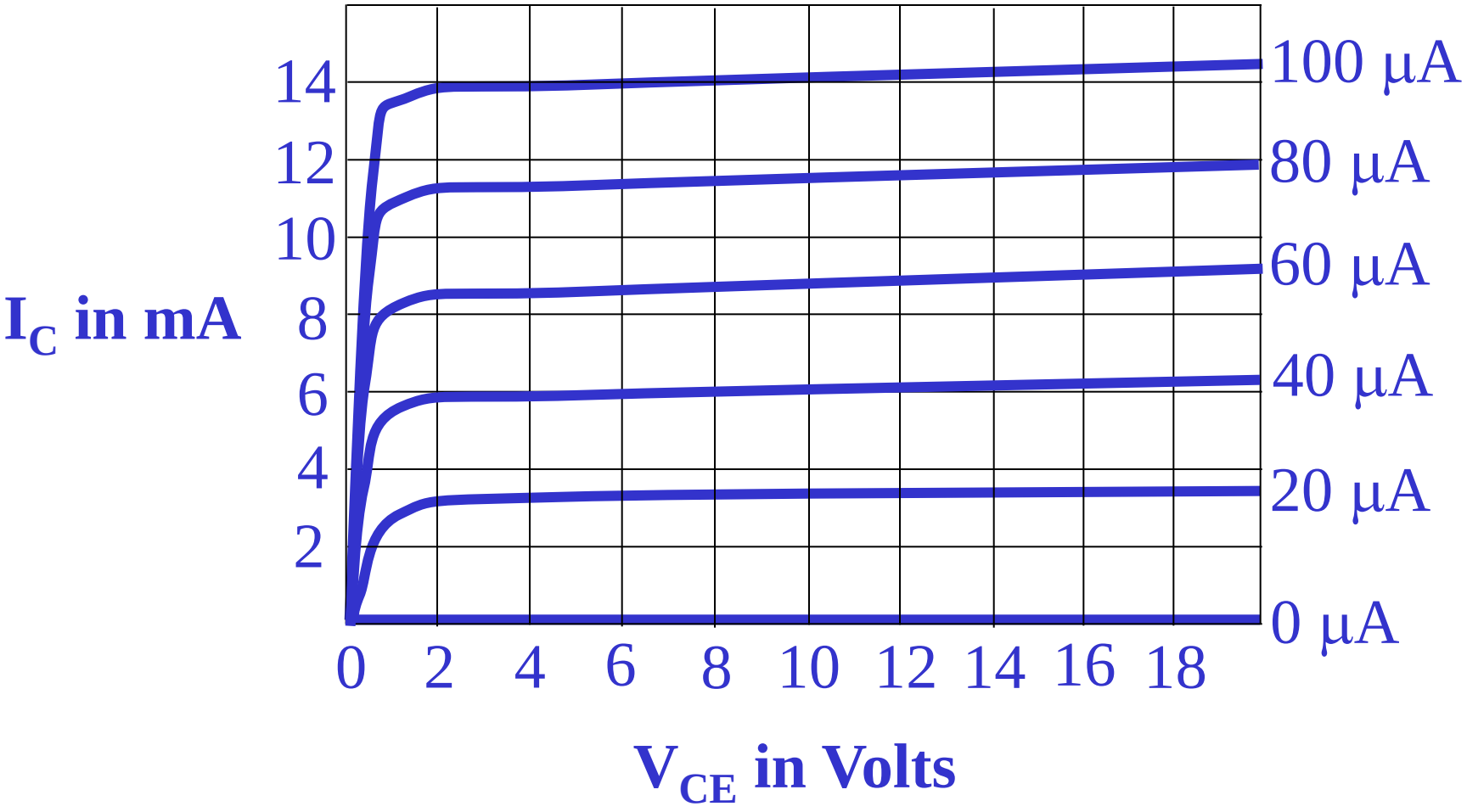
# The base circuit is usually analyzed with the same approximation used for diodes.

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



# A graph of $I_C$ versus $V_{CE}$

**(Note that each new value of $I_B$ presents a <u>new</u> curve.)**




**This set of curves is also called a <u>family</u> of curves.**

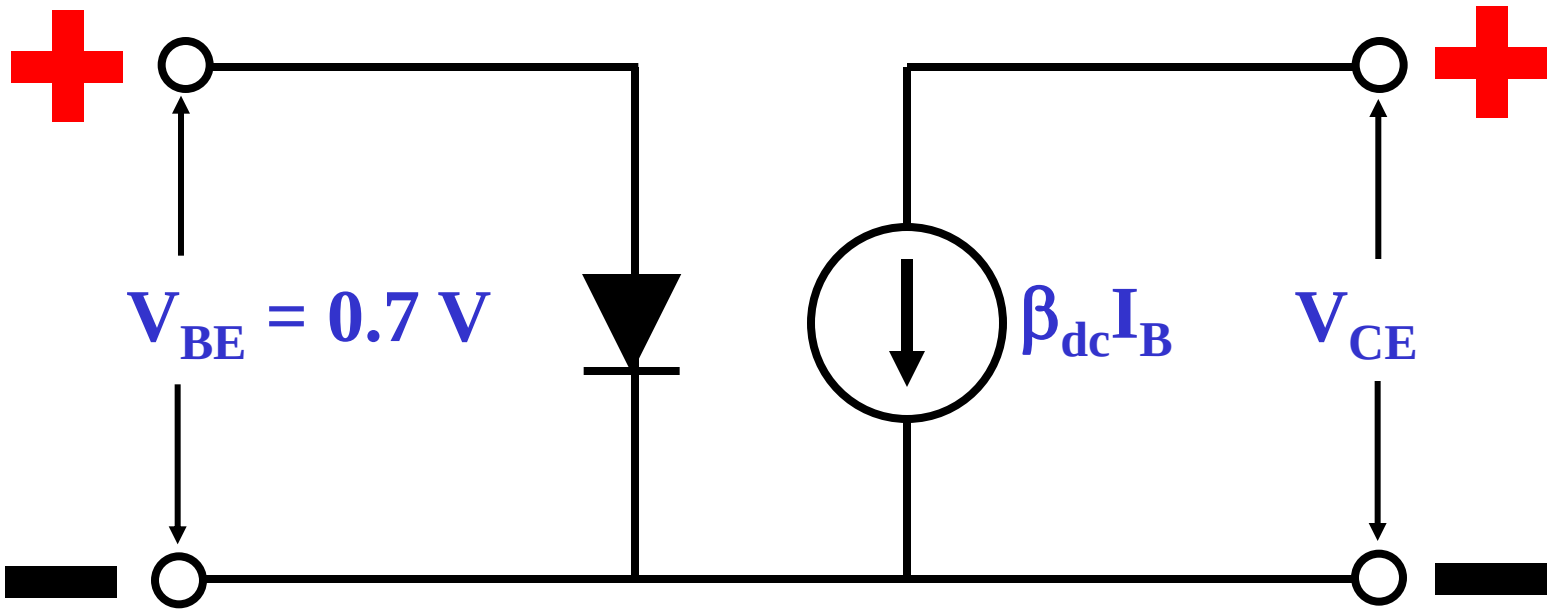
# Regions of operation

- **Active - - - used for linear amplification**
- **Cutoff - - - used in switching applications**
- **Saturation - - - used in switching applications**
- **Breakdown - - - can destroy the transistor and should be avoided**

# Transistor circuit approximations

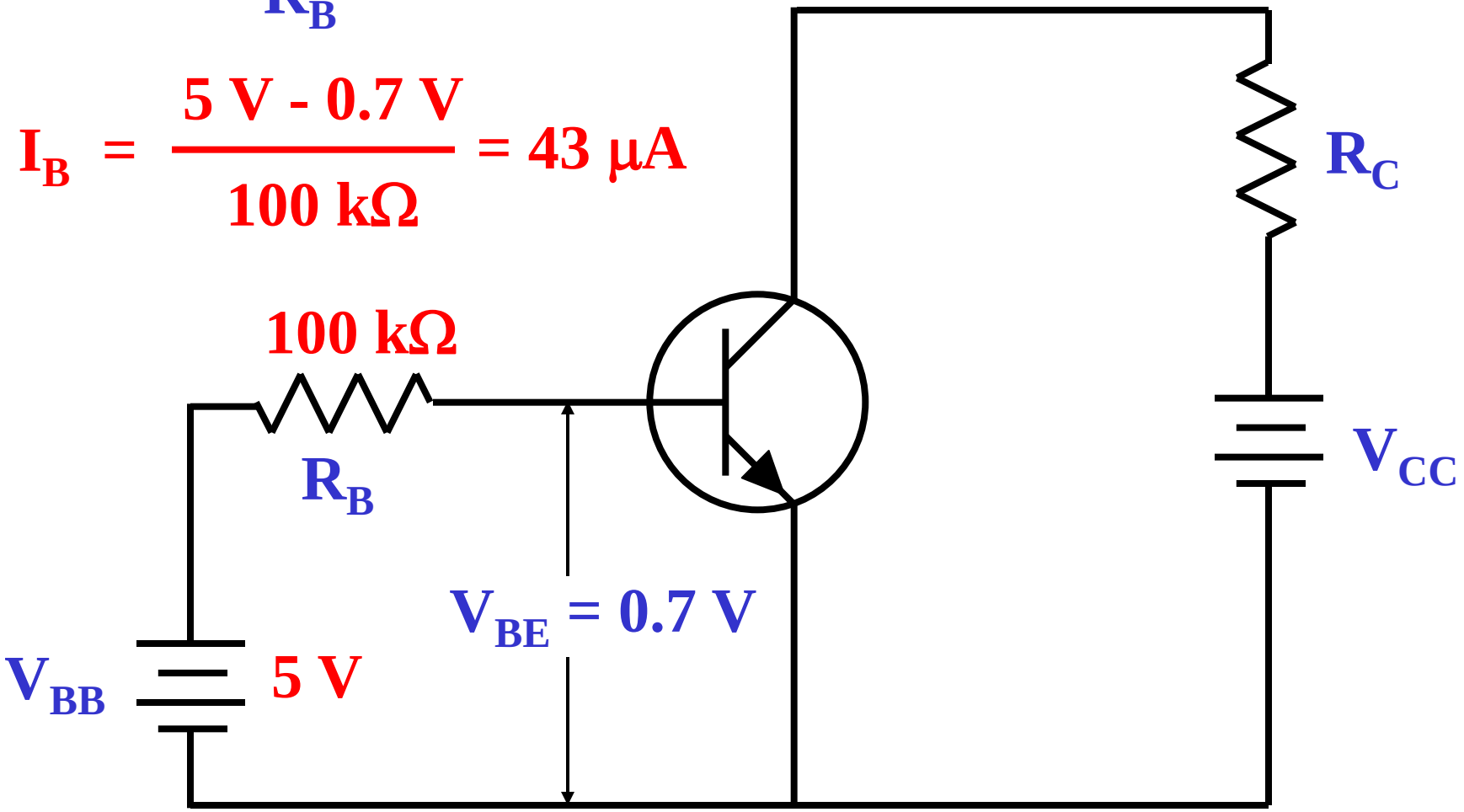
- **First:** treat the base-emitter diode as ideal and use $\beta I_B$ to determine $I_C$. Use for troubleshooting.
- **Second:** correct for $V_{BE}$ and use $\beta I_B$ to determine $I_C$.
- **Third (and higher):** correct for bulk resistance and other effects. Usually accomplished by computer simulation. Use for design work.

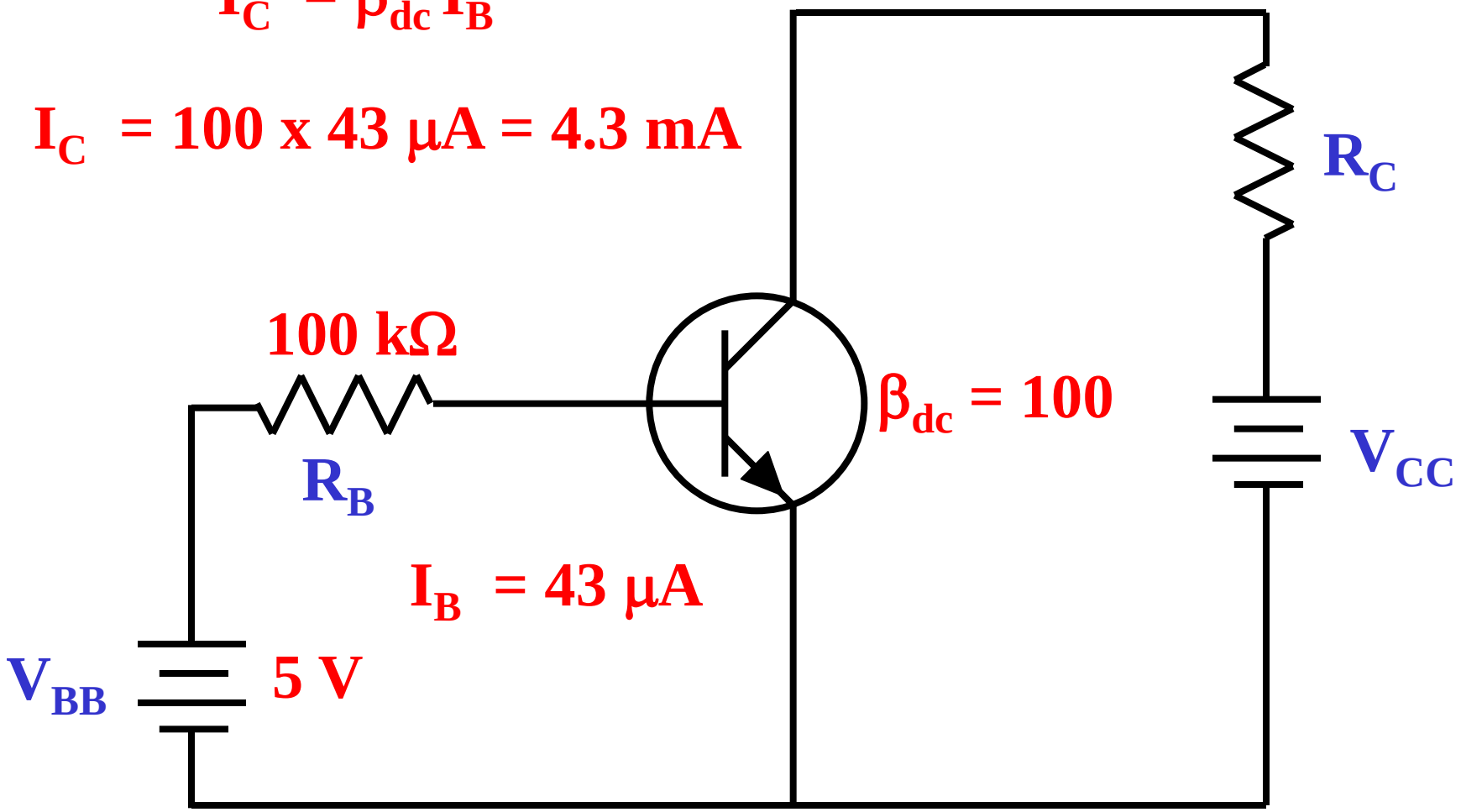
# The second approximation:

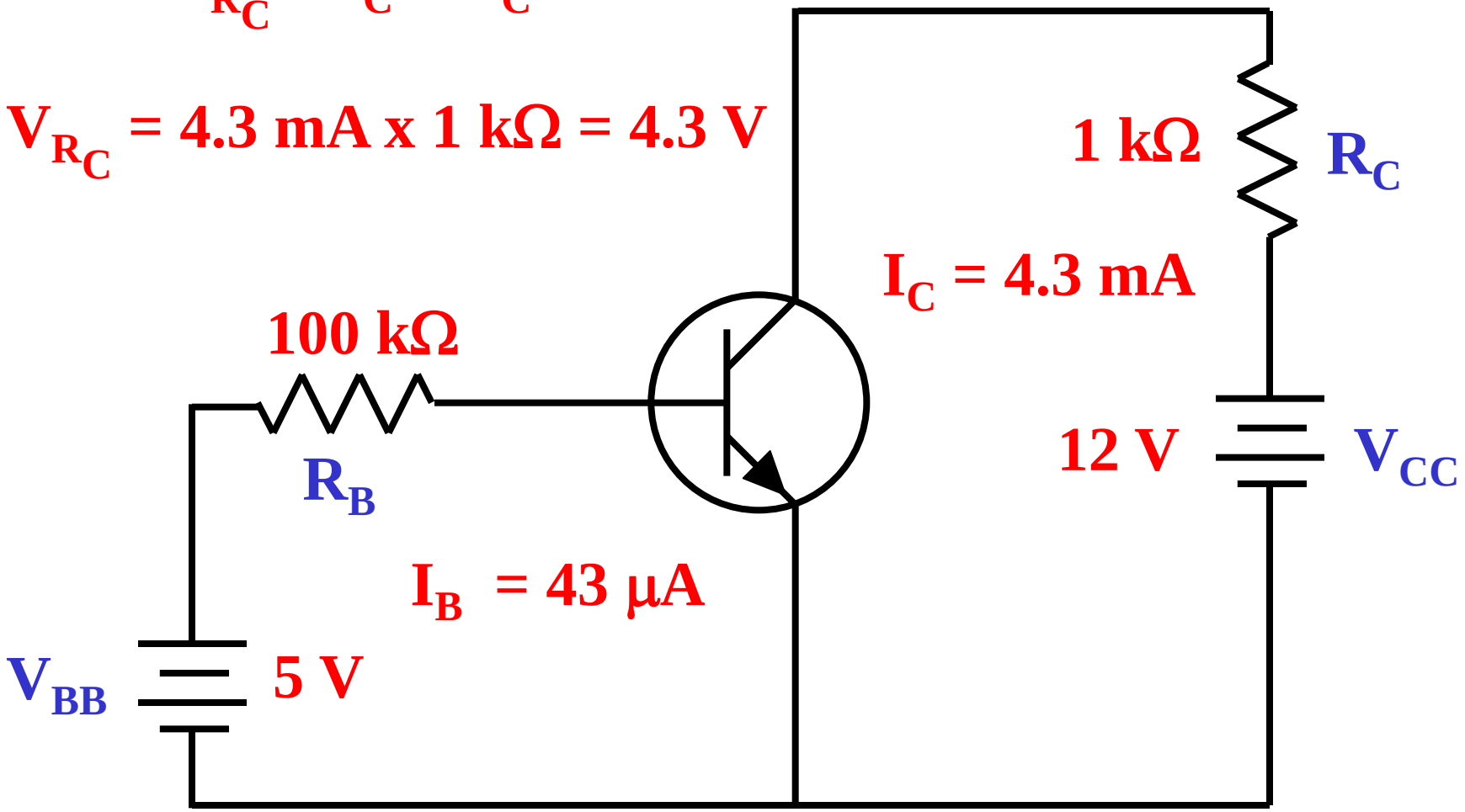


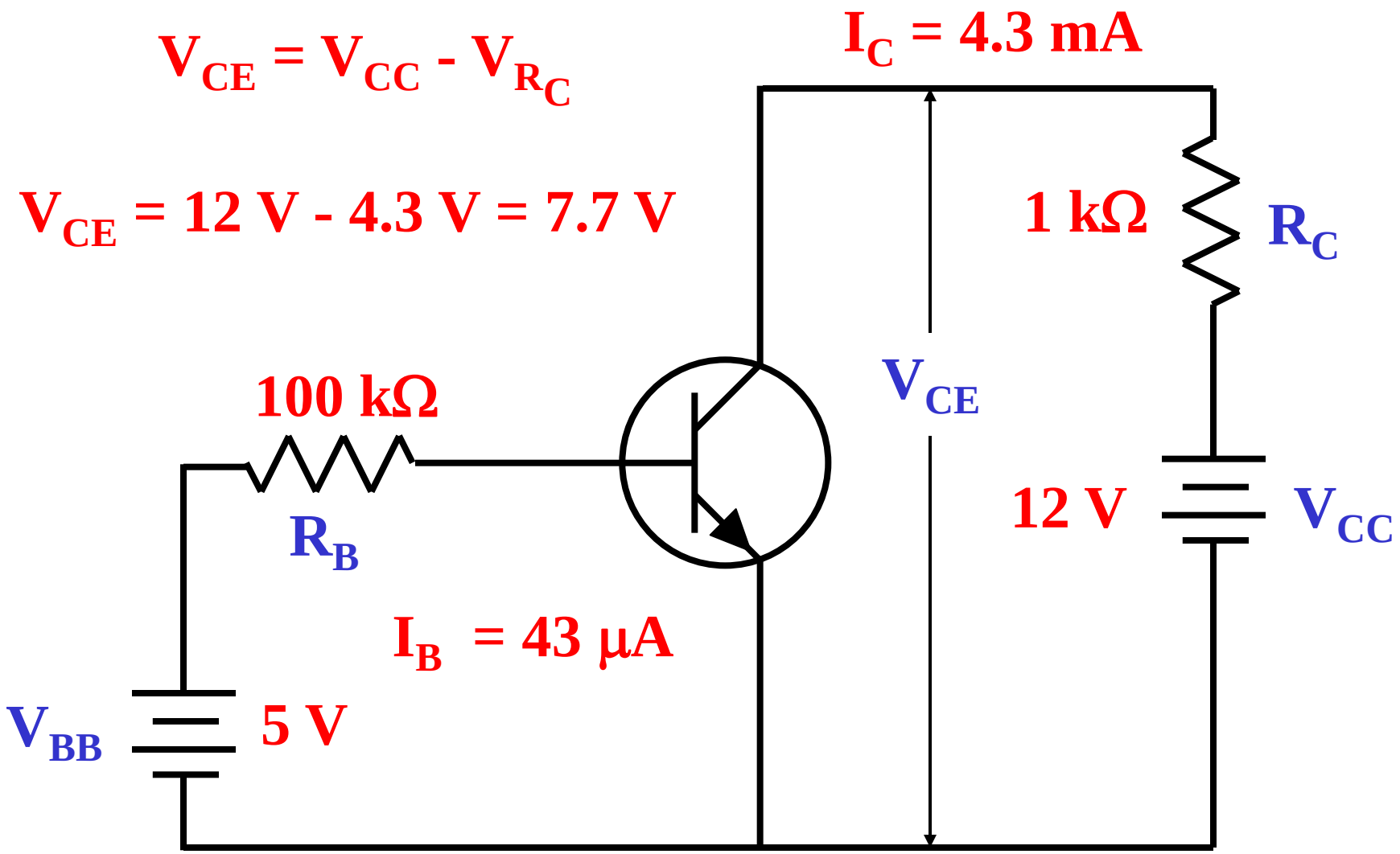
$$I_B = \frac{V_{BB} - V_{BE}}{R_B}$$

$$I_B = \frac{5\ V - 0.7\ V}{100\ k\Omega} = 43\ \mu A$$









# Reading transistor data sheets

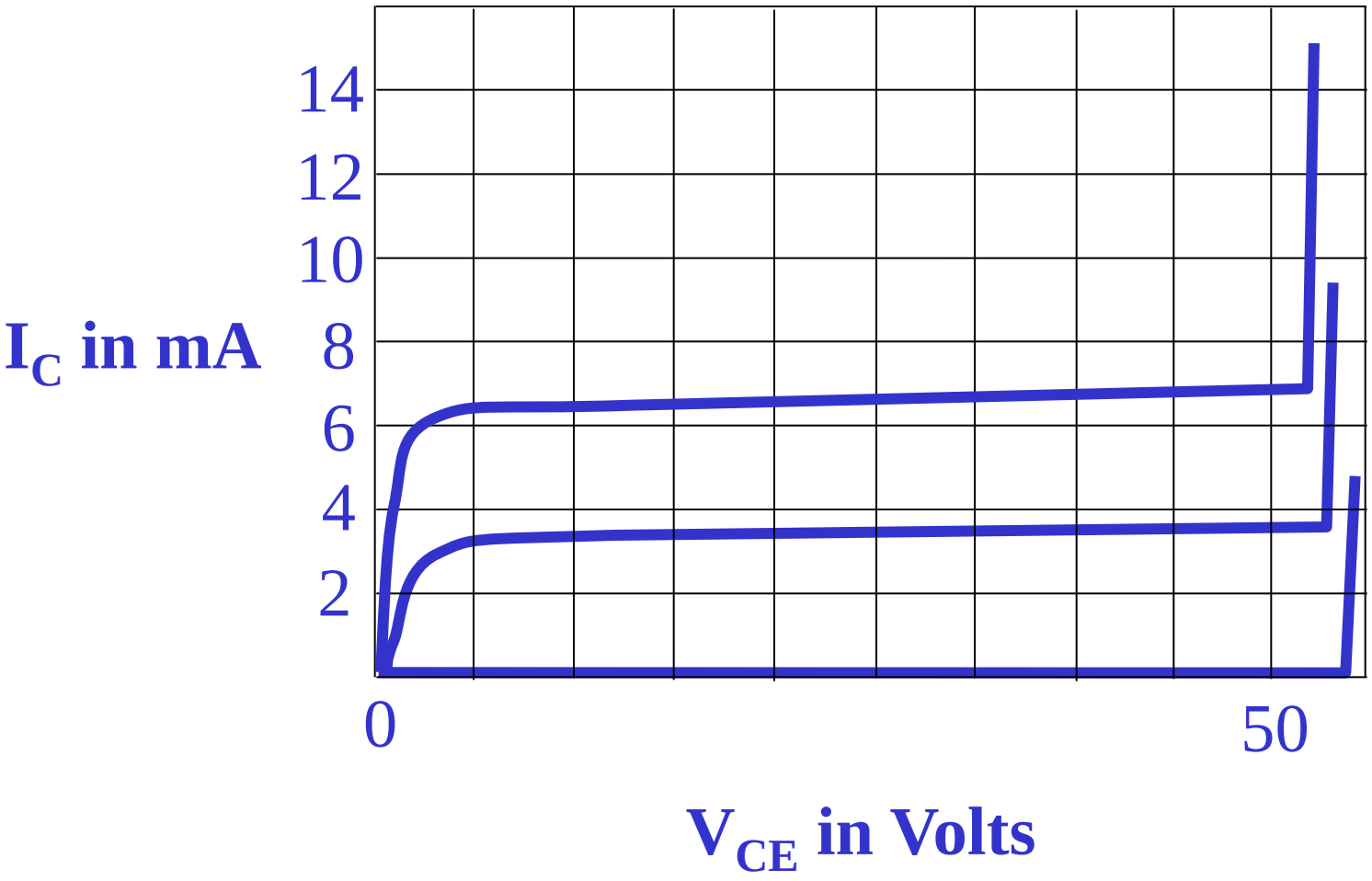
- Maximum ratings on voltage, current, and power
- Power transistors dissipate more than 1 watt
- Temperature can change the value of a transistor's characteristics

# Typical Breakdown Ratings

- $V_{CBO}$ = 60 V
- $V_{CEO}$ = 40 V
- $V_{EBO}$ = 6 V

- **Note: these are reverse breakdown ratings with one transistor leg open (e.g. $V_{CBO}$ is voltage collector to base with emitter open)**

# A graphic view of collector breakdown



# Typical Maximum Ratings

- $I_C$ = 200 mA dc
- $P_D$ = 250 mW (for $T_A$ = 60 °C)
- $P_D$ = 350 mW (for $T_A$ = 25 °C)
- $P_D$ = 1 W (for $T_C$ = 60 °C)

# Data sheet $h_{FE}$ "On Characteristics"

| $I_C$ in mA | $h_{FE(min)}$ | $h_{FE(max)}$ |
|---|---|---|
| 0.1 | 40 | ___ |
| 1 | 70 | ___ |
| 10 | 100 | 300 |
| 50 | 60 | ___ |
| 100 | 30 | ___ |

# Surface-mount transistors

- A variety of package styles (three-terminal gull-wing is typical)
- Some SMTs can dissipate 1 watt or more
- Some SMTs house multiple transistors

# Troubleshooting

- Look for gross voltage errors.
- First approximation and mental estimates will usually suffice.
- Resistors generally don't short but circuit boards can.
- Circuit boards  can and do open.
- Junctions can and do short.
- Junctions can and do open.