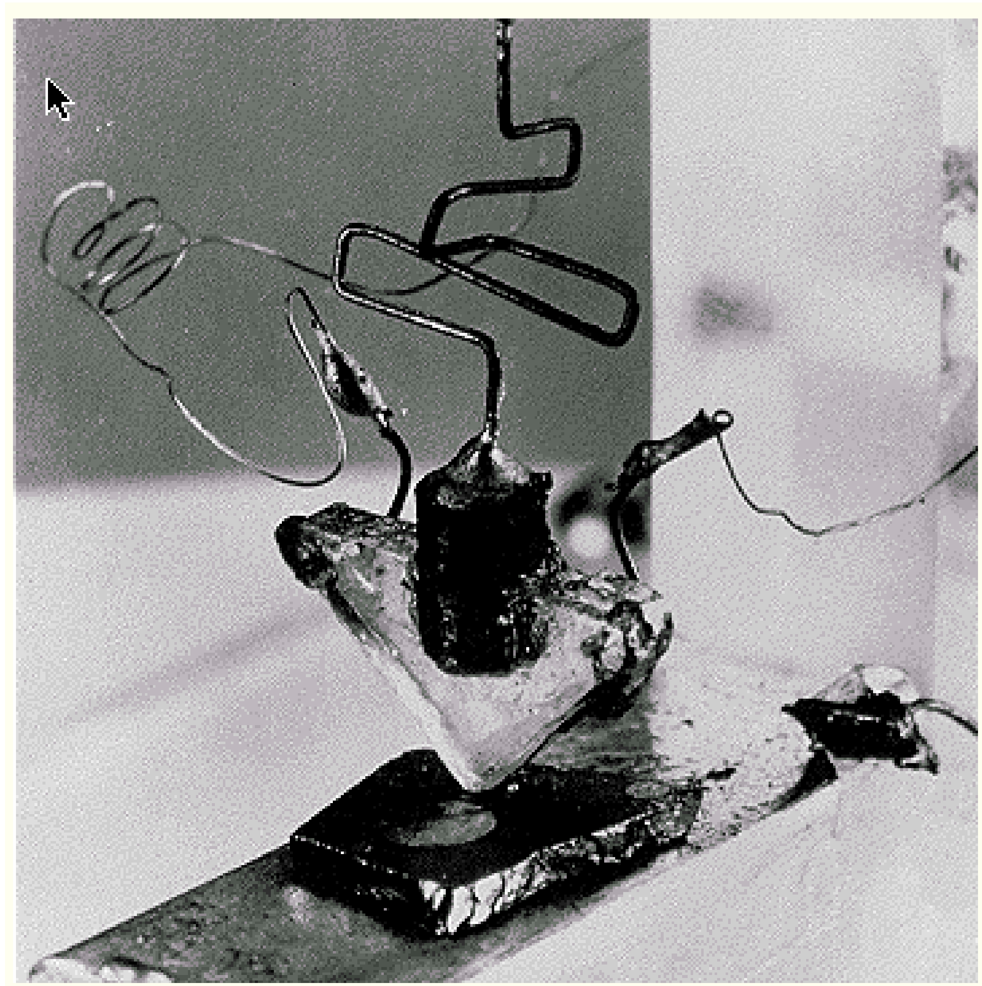
# Bipolar Junction Transistors (BJT)

Signal amplification is important in many applications, such as telecommunications. Before the advent of transistors, signal amplification was accomplished using vacuum tubes. Transistors are much smaller and do not need a long warm-up time needed with vacuum tubes. The invention of the bipolar junction transistor started a revolution which placed electronics on a path of miniaturization; a fact that would have been impossible with vacuum tubes.

**In summary, the transistor and subsequently the integrated circuit must certainly qualify as two of the greatest inventions of the twentieth century.**

# The First Transistor

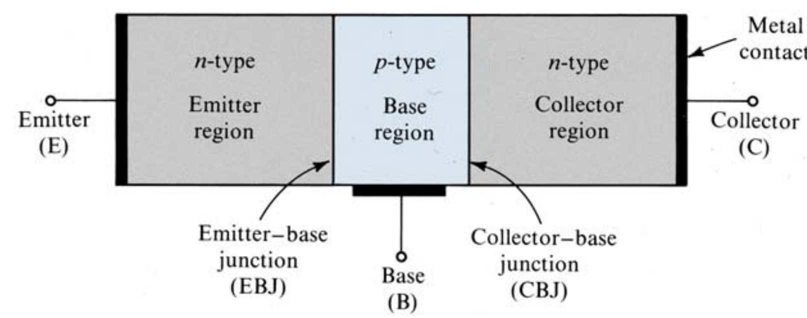
Dr. Lindsey Archive http://www.cs.colorado.edu/~lindsay/index.html

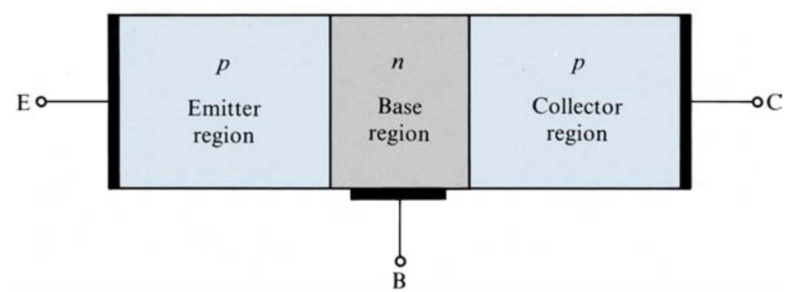


# BJT Structure

**By placing two PN junctions together we can create a bipolar transistor.A BJT transistor has three terminals. The base (B), the collector (C), and the emitter (E).**

- Transistors are three-terminal devices. The terminals are labelled the base, the emitter and the collector. Each BJTs consist of two *pn* junctions (where a '*p* type' material joins to a 'n type material'). Therefore, a transistor may be made up from a piece of *p* type material sandwiched between two n type regions (*npn*), or it may be made up from a piece of 'n type' material sandwiched between two 'p type' regions (*pnp*)



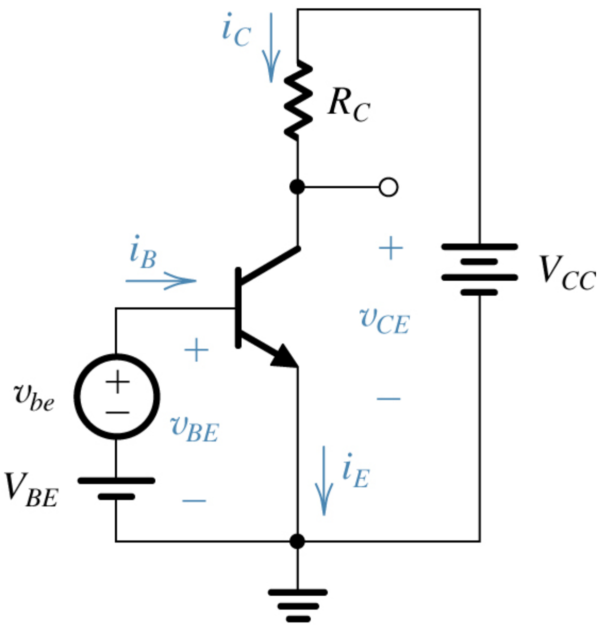
# The Transistor as an Amplifier: DC Condition

The transistor should be in the active region. Biasing means establishing a constant DC current in the emitter or the collector. The operation of the transistor as an amplifier is highly influenced by the value of the quiescent (bias) current.

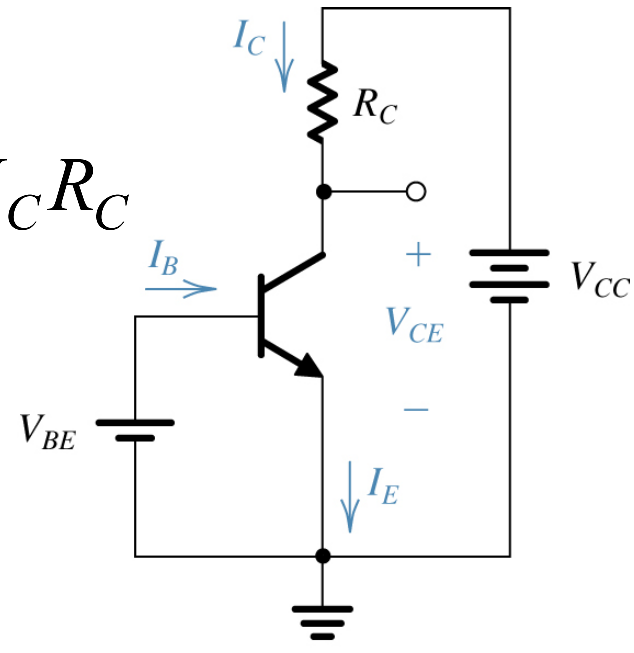
$$I_E = I_C / \alpha$$

$$I_B = I_C / \beta$$

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



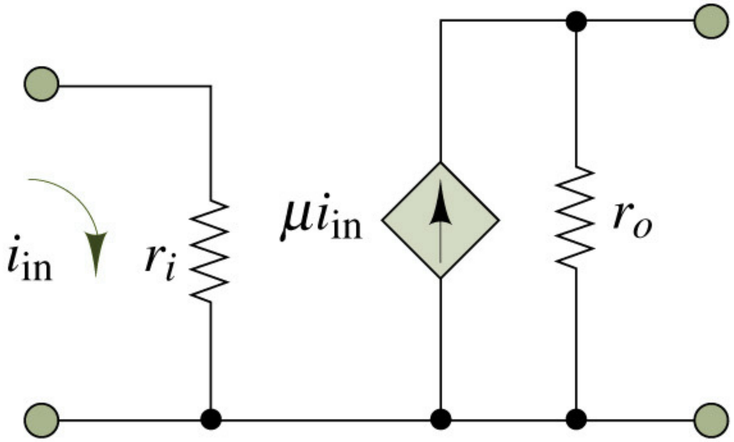

(a)



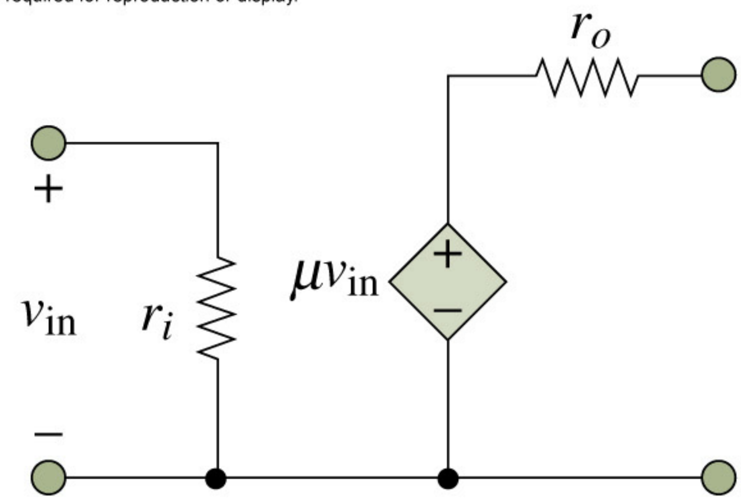

(b)

# Controlled-Source Models of Linear Amplifier Transistor Operation

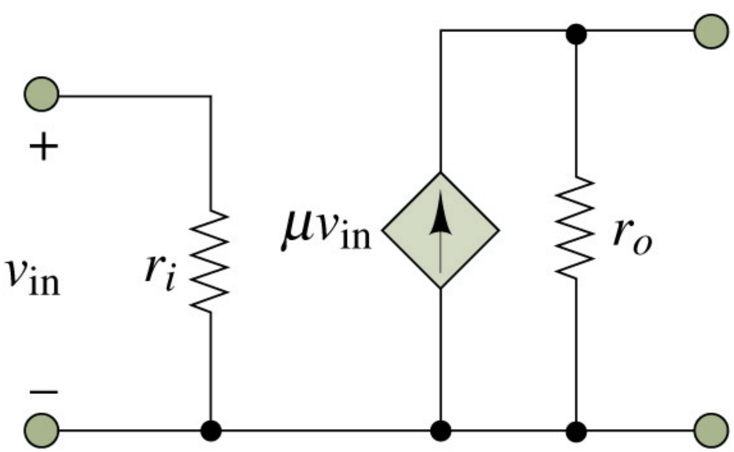




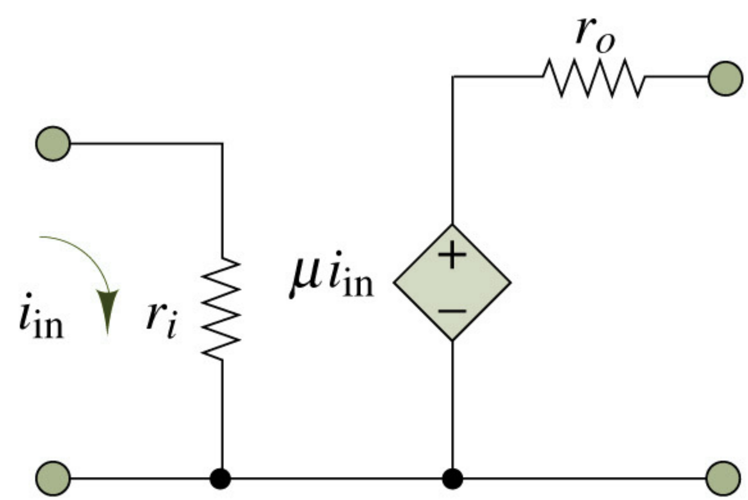

(a) Current-controlled current source




(b) Voltage-controlled voltage source



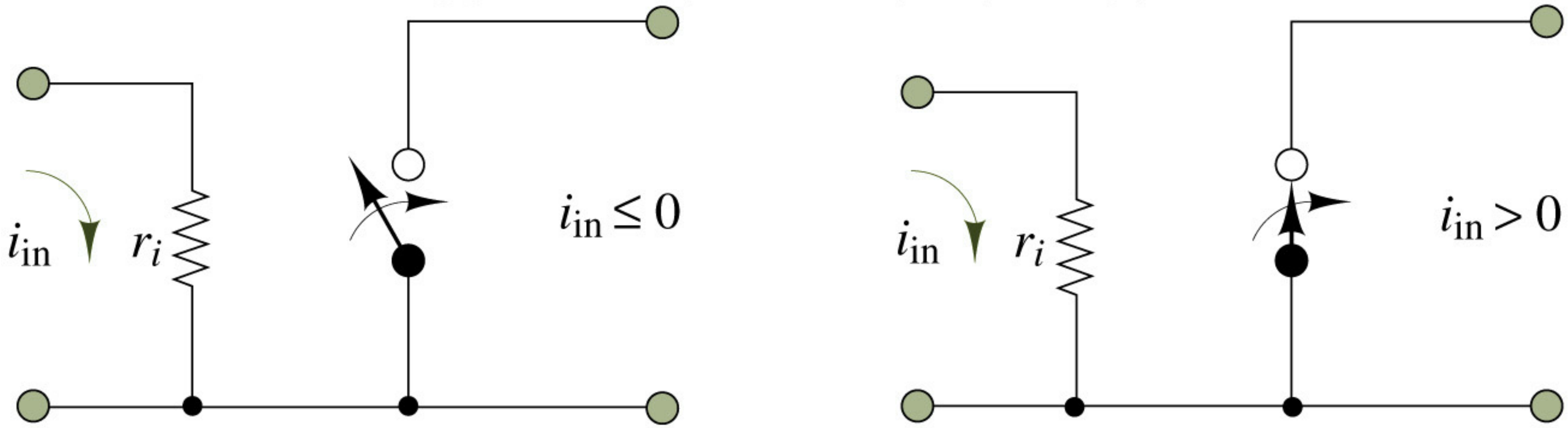

(c) Voltage-controlled current source



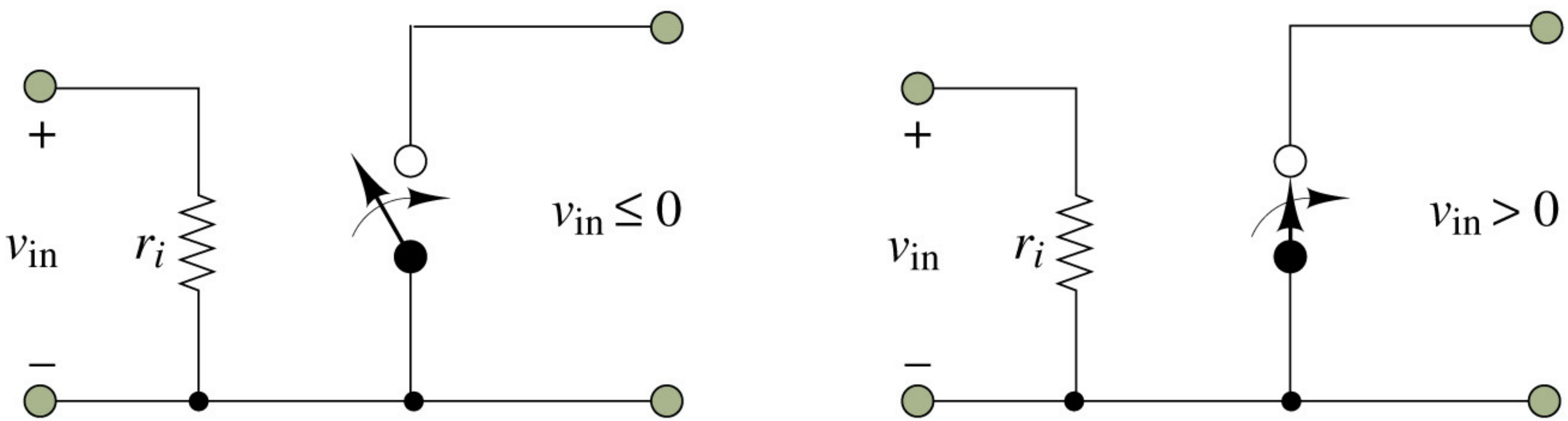

(d) Current-controlled voltage source

# Models of Ideal Transistor Switches





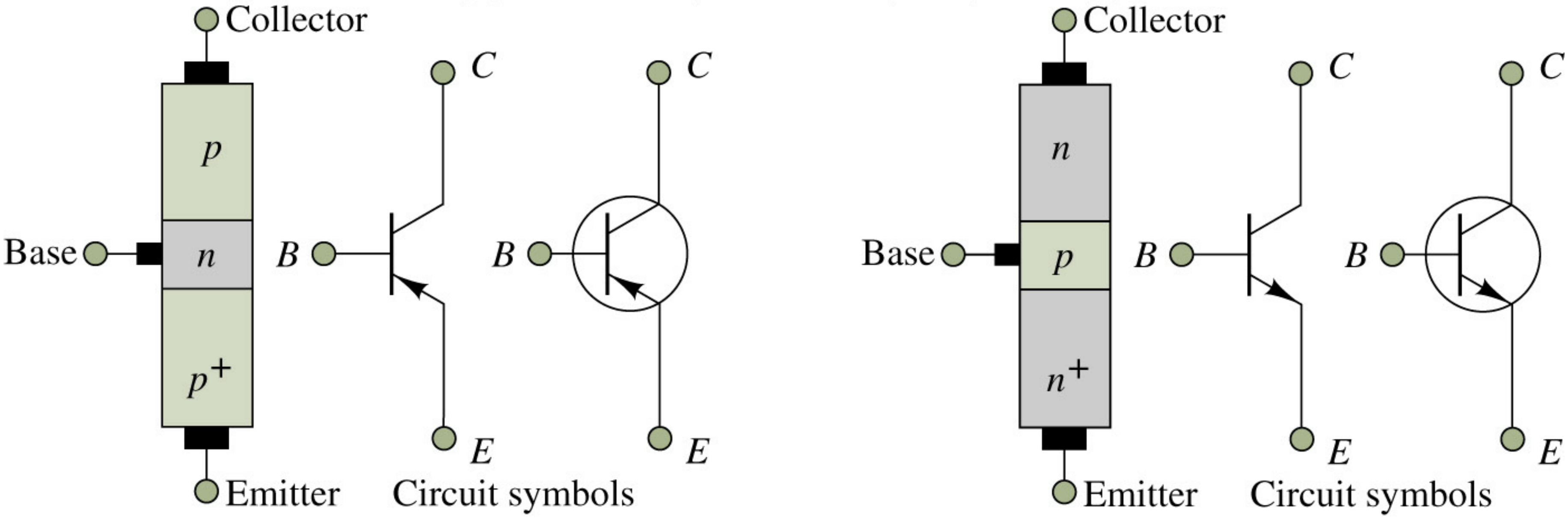

Current-controlled switch




Voltage-controlled switch

# Bipolar Junction Transistors



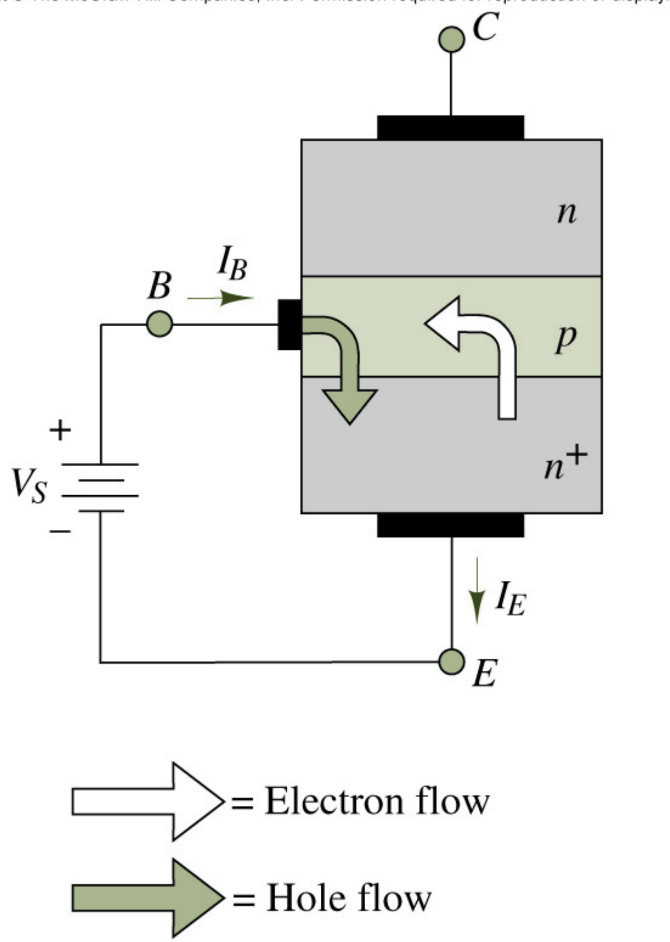



*pnp* transistor

*npn* transistor

# Current Flow in an *npn* BJT

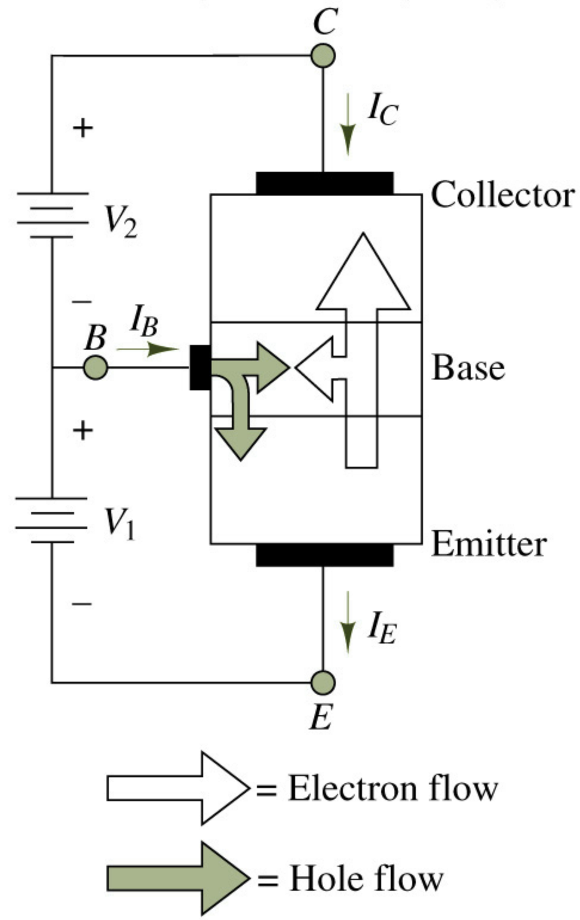





The *BE* junction acts very much as an ordinary diode when the collector is open. In this case, $I_B = I_E$.

# Flow of Emitter Electrons into the Collector in an *npn* BJT



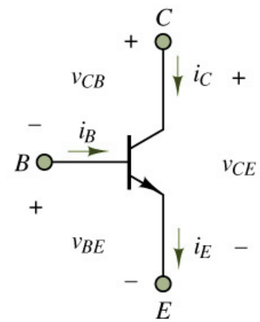



When the *BC* junction is reverse-biased, the electrons from the emitter region are swept across the base into the collector.

# Definition of BJT Voltages and Currents



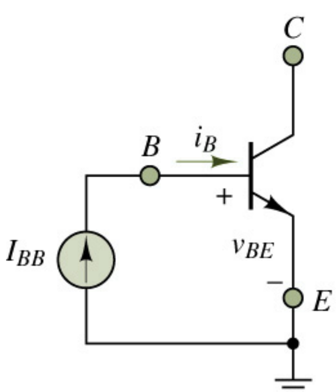
The operation of the BJT is defined in terms of two currents and two voltages: $i_B$, $i_C$, $v_{CE}$, and $v_{BE}$.

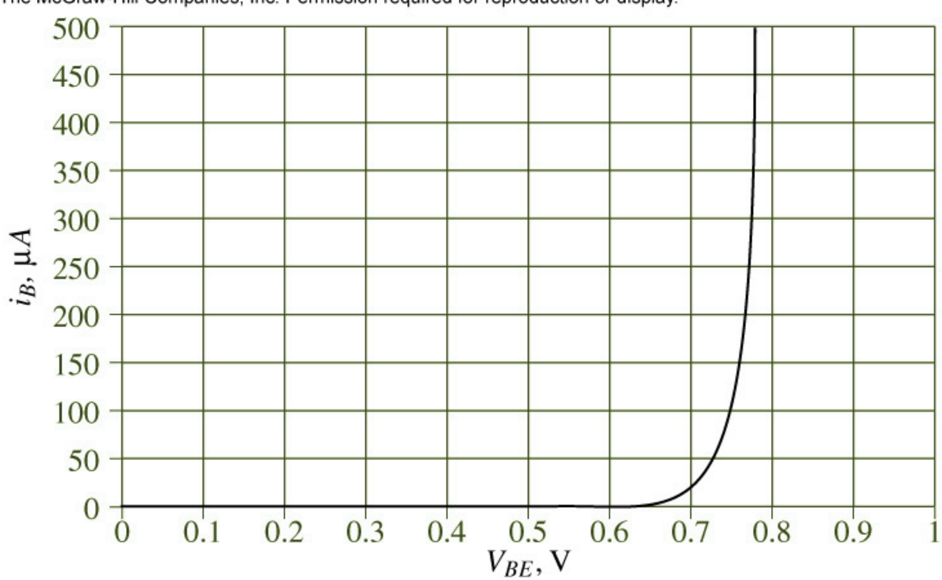



KCL: $i_E = i_B + i_C$
KVL: $v_{CE} = v_{CB} + v_{BE}$

# The *BE* Junction Open-Collector Curve

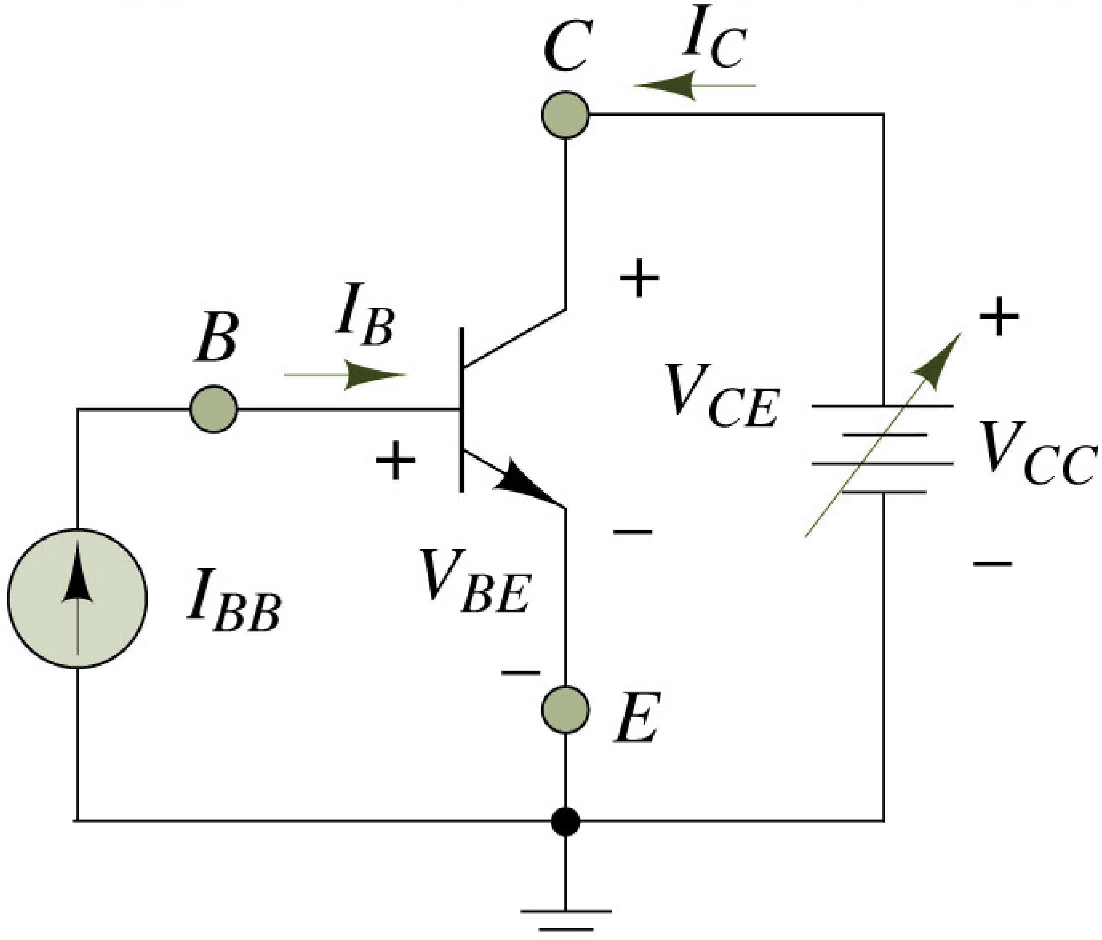




# Ideal Test Circuit to Determine the *i-v* Characteristic of a BJT

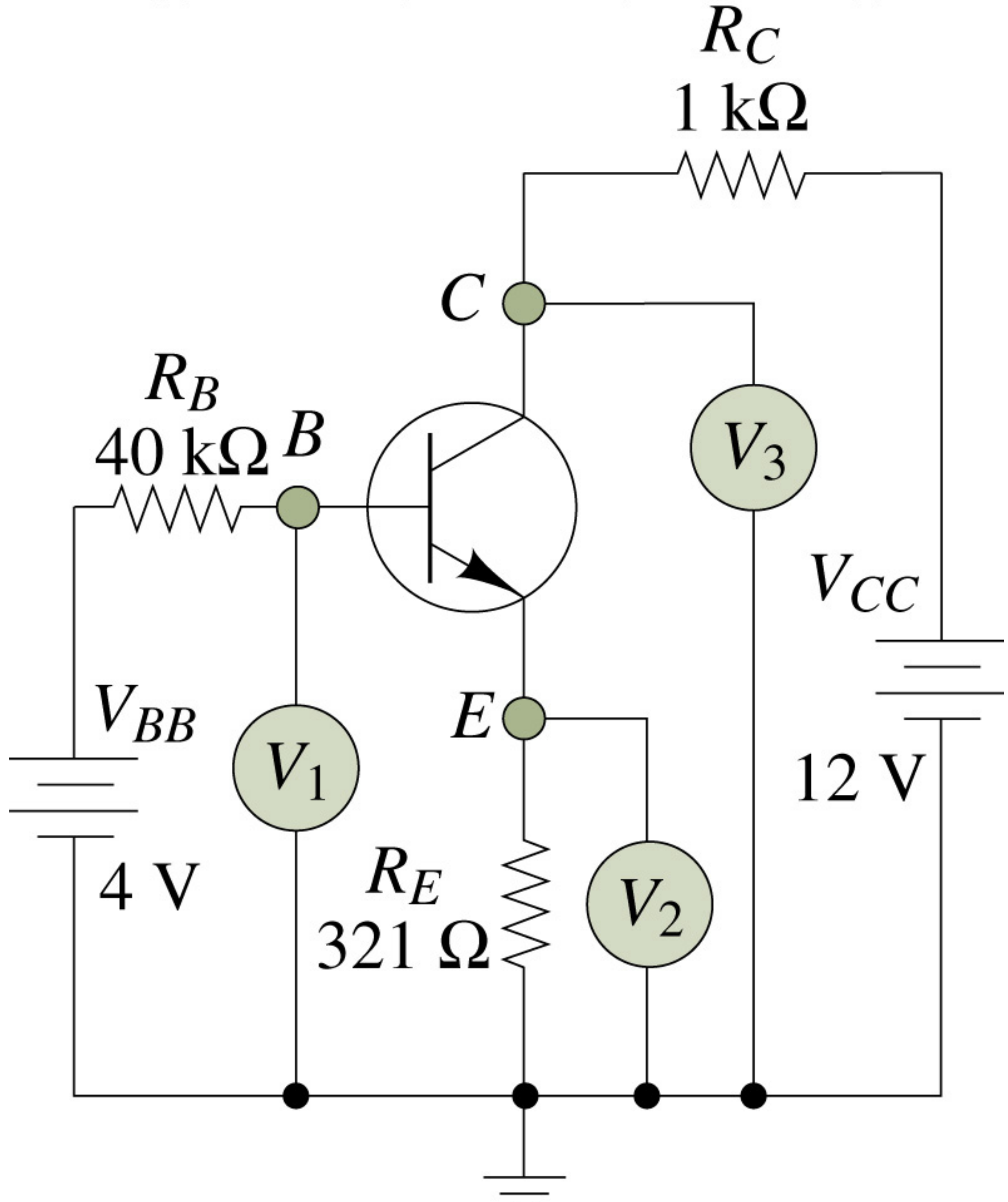





(a)

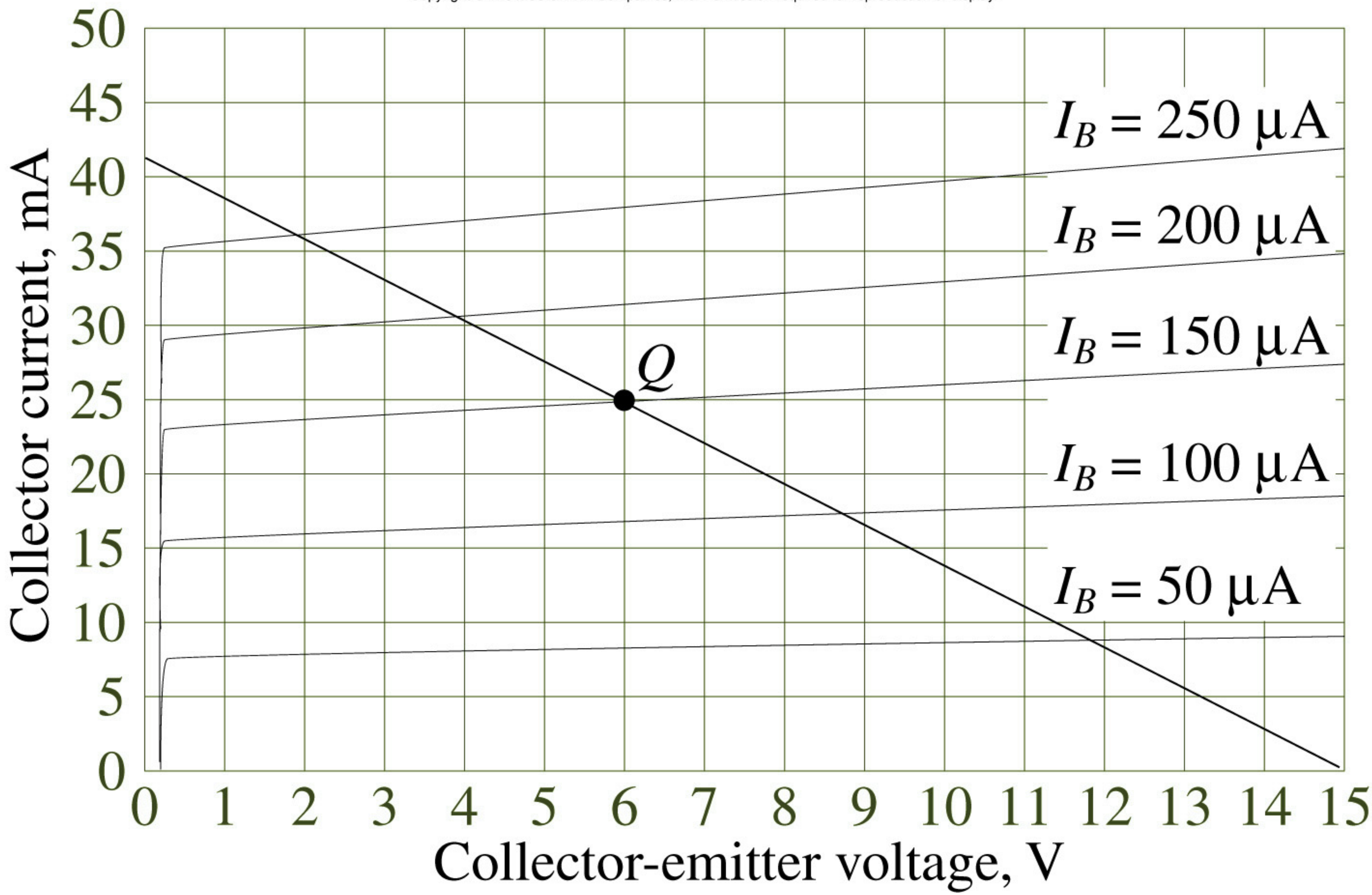
# Determination of the Operation Region of a BJT





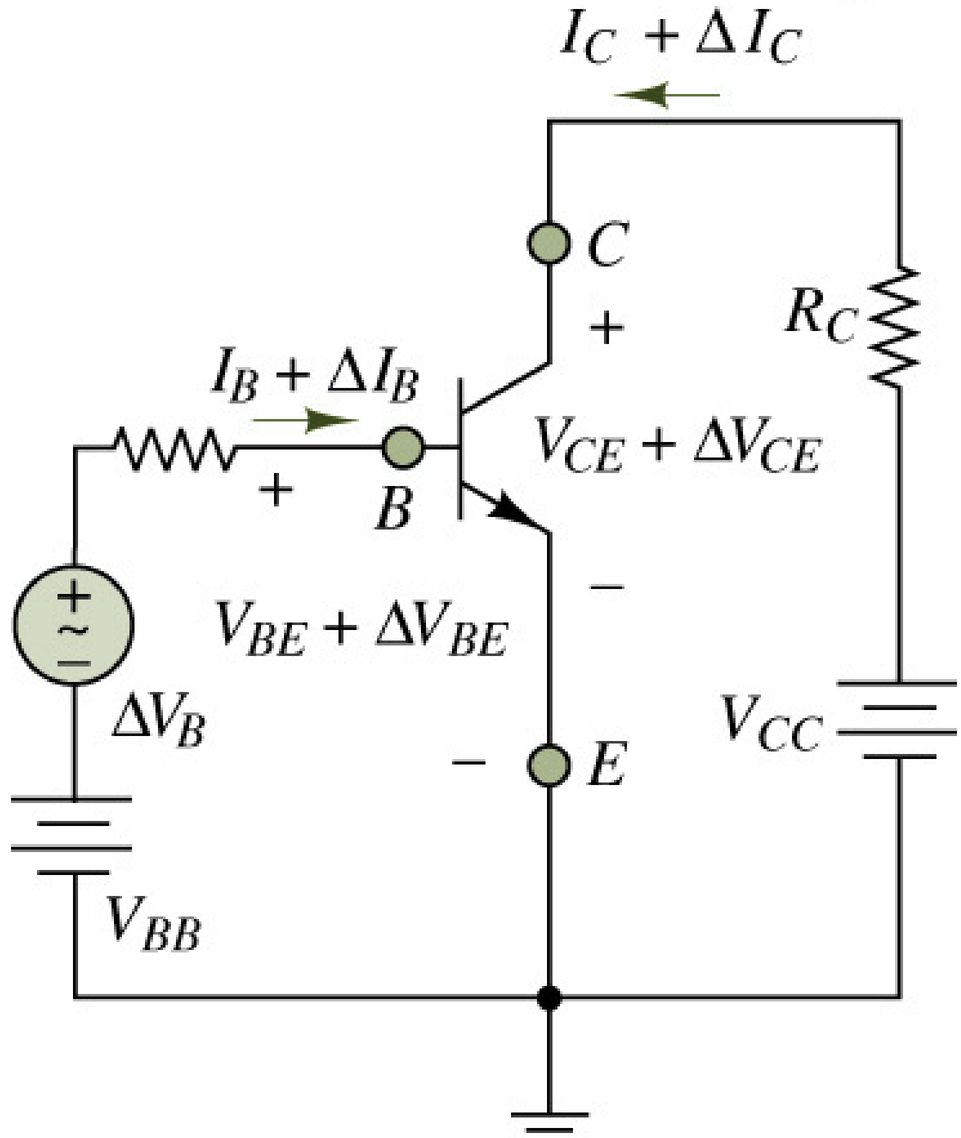
# Load-line Analysis of a Simplified BJT Amplifier





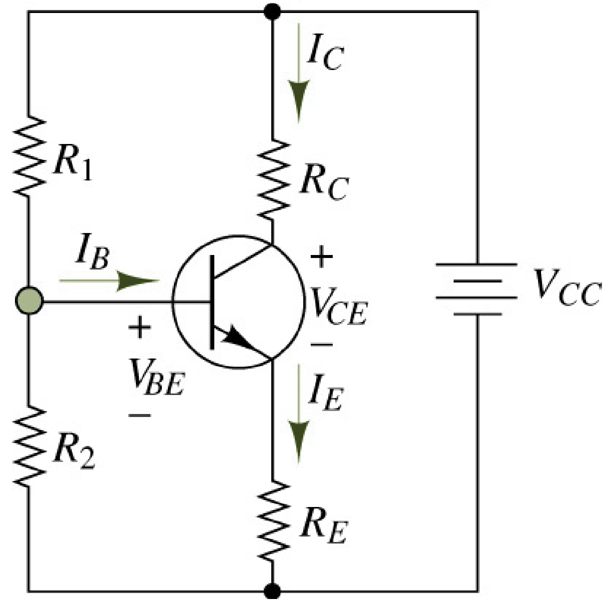
# Circuit Illustrating the Amplification Effect in a BJT





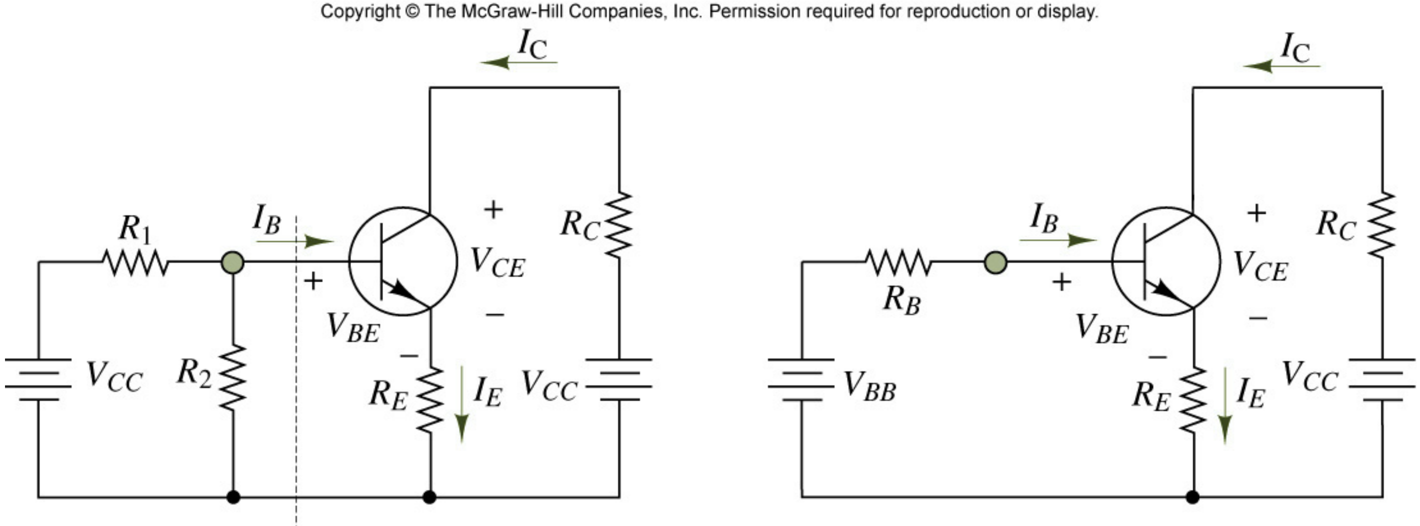
# Practical BJT Self-Bias DC Circuit






# DC Self-Bias Circuit Represented in Equivalent-Circuit Form






(a) (b)

$$i_C = I_s e^{v_{BE}/V_T}$$

$$i_B = \frac{i_C}{\beta} = \left(\frac{I_S}{\beta}\right) e^{v_{BE}/V_T}$$

$$i_E = \frac{i_C}{\alpha} = \left(\frac{I_S}{\alpha}\right) e^{v_{BE}/V_T}$$

$$i_C = \alpha i_E ; i_B = (1-\alpha) i_E = \frac{i_E}{\beta+1}$$

$$i_C = \beta i_B ; i_E = (\beta+1) i_B$$

$$\beta = \frac{\alpha}{1-\alpha}$$

- The basic principle involves the use of the voltage between two terminals to control the current flowing in the third terminal.
- Current is conducted by both electrons and holes, therefore the name bipolar.
- $\alpha$ is called the common-base current gain.
- $\beta$ is called the common-emitter current gain.

# DC Analysis of Transistor Circuits

## Common-Emitter Configuration

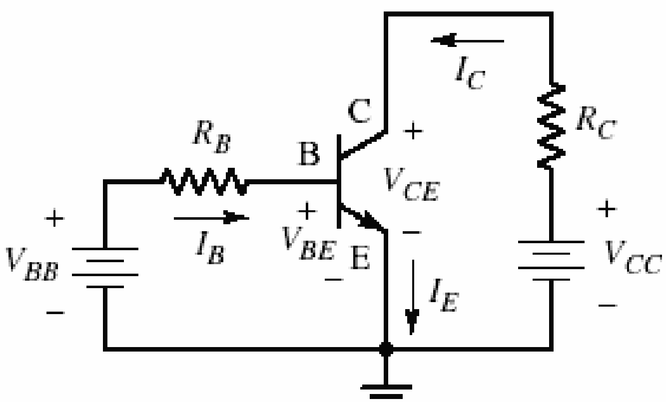
Electronic Circuit Analysis and Design, Neamem, 2001

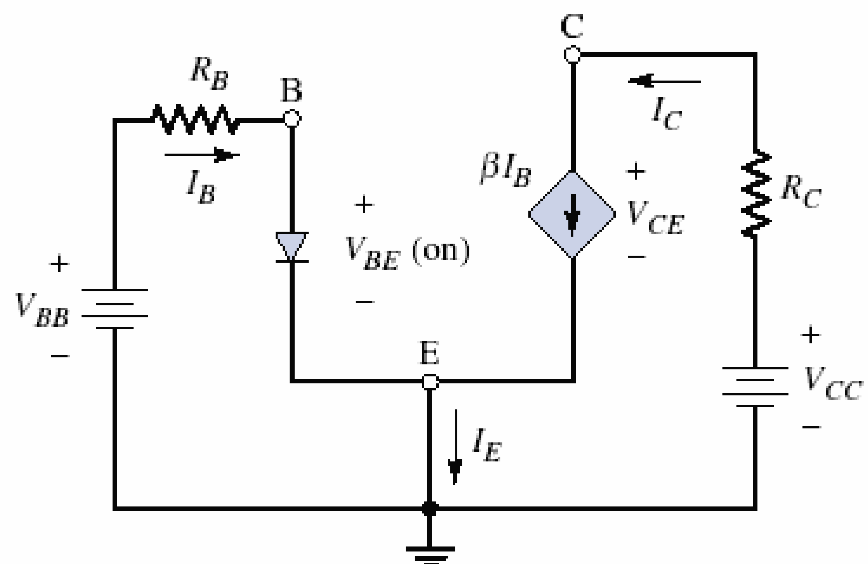
$$I_B = \frac{V_{BB} - V_{BE}}{R_B}$$

$$I_C = \beta I_C$$

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

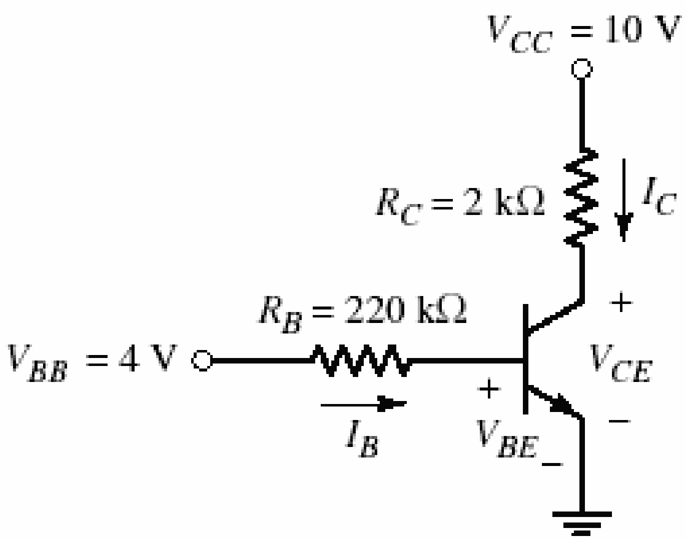
$$V_{CE} = V_{CC} - I_C R_C$$

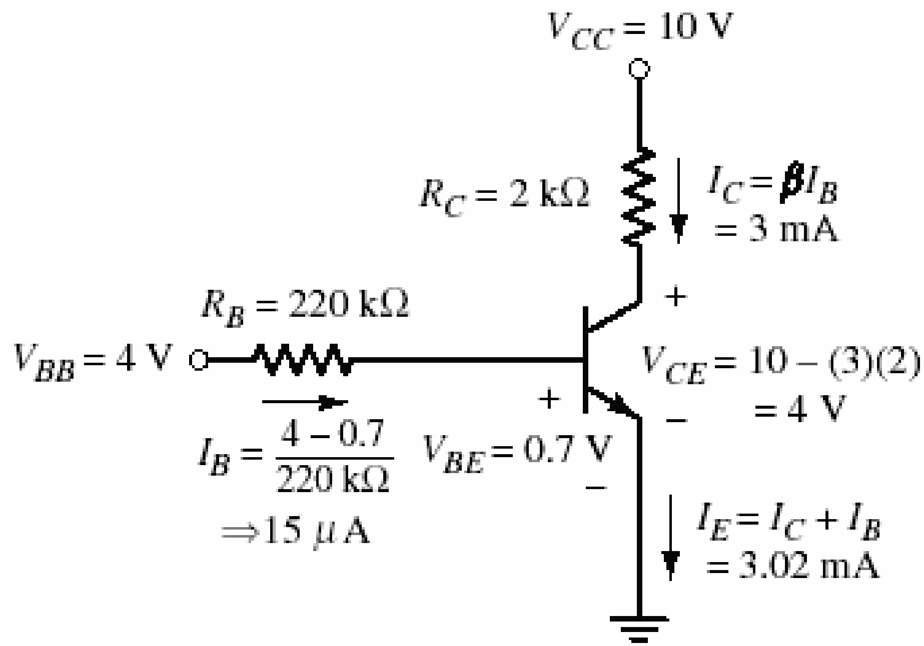


**Example:** Calculate the base, collector, and emitter currents and the CE voltage for the following committer circuit when $\beta = 200$, $V_{BE} = 0.7$

(Electronic Circuit Analysis and Design, Neamem)



# Amplifier in a Circuits

## Block Diagram of a Compact Disc Player System

Neamem, Electronic Circuit Analysis and Design, McGraw Hill, 2001