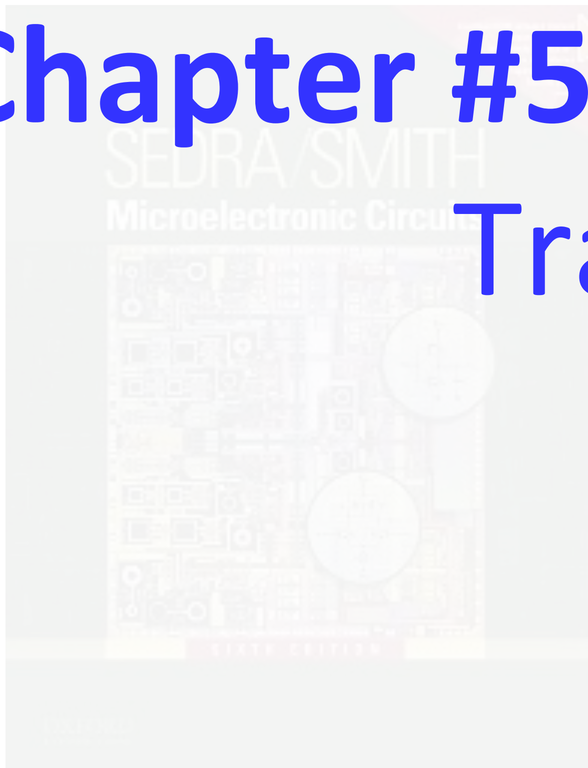
Chapter #5: Bipolar Junction Transistors



Introduction

- **IN THIS CHAPTER YOU WILL LEARN**
  - The physical structure of the bipolar transistor and how it works.
  - How the voltage between two terminals of the transistor controls the current that flows through the third terminal, and the equations that describe these current-voltage relationships.
  - How to analyze and design circuits that contain bipolar transistors, resistors, and dc sources.
  - How the transistor can be used to make an amplifier.

Introduction

- **IN THIS CHAPTER YOU WILL LEARN**
  - How to obtain linear amplification from the fundamentally nonlinear BJT.
  - The three basic ways for connecting a BJT to be able to construct amplifiers with different properties.
  - Practical circuits for bipolar-transistor amplifiers that can be constructed by using discrete components.

Introduction

- This chapter examines another three-terminal device.
  - **bipolar junction transistor**
  - Presentation of this material mirrors chapter 5.
- BJT was invented in 1948 at Bell Telephone Laboratories.
  - Ushered in a new era of solid-state circuits.
  - It was replaced by MOSFET as predominant transistor used in modern electronics.

5.1. **Device Structure and Physical Operation**

- Figure 5.1. shows simplified structure of BJT.
- Consists of three semiconductor regions:
  - **emitter** region (*n*-type)
  - **base** region (*p*-type)
  - **collector** region (*n*-type)
- Type described above is referred to as *npn*.
  - However, *pnp* types do exist.

5.1.1. **Simplified Structure and Modes of Operation**

- Transistor consists of two *pn*-junctions:
  - **emitter-base** junction (EBJ)
  - **collector-base** junction (CBJ)
- Operating mode depends on biasing.
  - **active** mode – used for amplification
  - **cutoff** and **saturation** modes – used for switching.

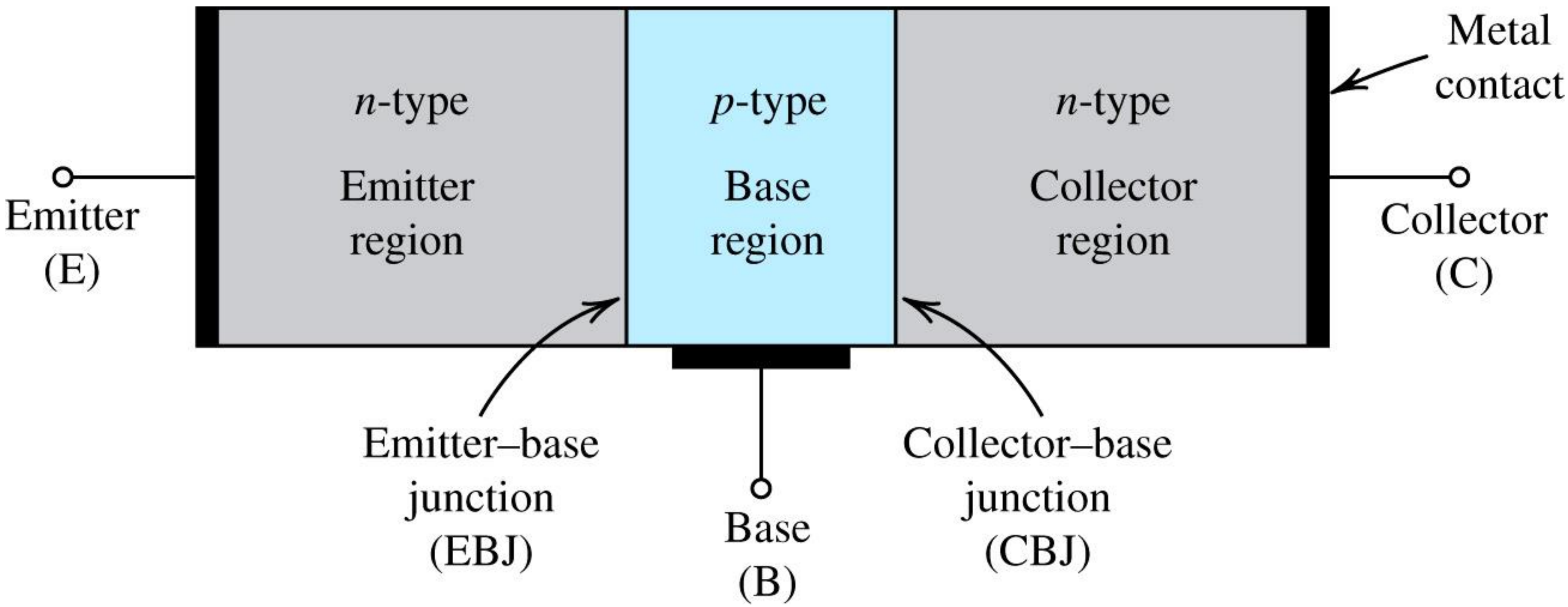


Figure 5.1: A simplified structure of the *npn* transistor.

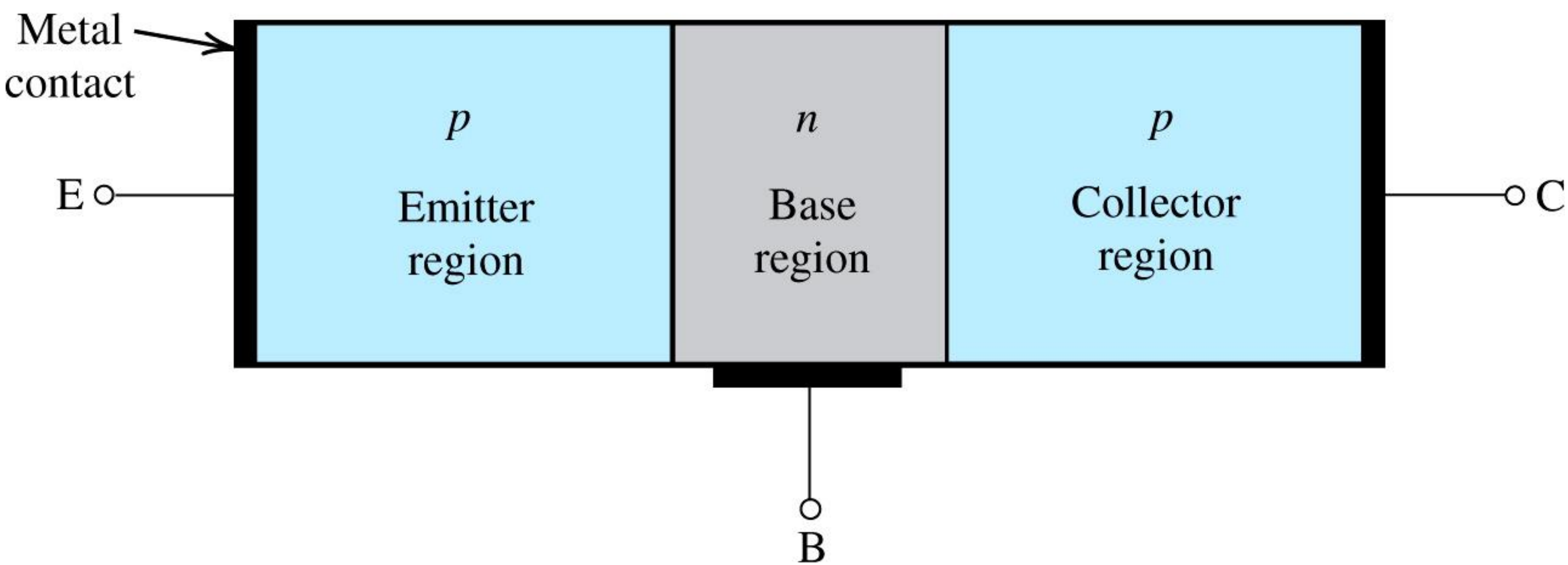


Figure 5.2: A simplified structure of the *pnp* transistor.

Modes Of Operation in BJT

- There are two diode PN junctions involved – Emitter Base or EB and Collector Base or CB.
- Each can be set in forward or reverse mode. This gives rise to 4 combinations:

Mode	EB Junction	CB Junction	Used as
Cut Off	**Reverse**	**Reverse**	**Switch OFF**
Active	**Forward**	**Reverse**	**Amplifier**
Reverse Active	**Reverse**	**Forward**	**Not Used**
Saturation	**Forward**	**Forward**	**Switch ON**

5.1.2. **Operation of the *npn*-Transistor in the Active Mode**

- Active mode is "most important."
- Two external voltage sources are required for biasing to achieve it.
- Refer to Figure 5.3.

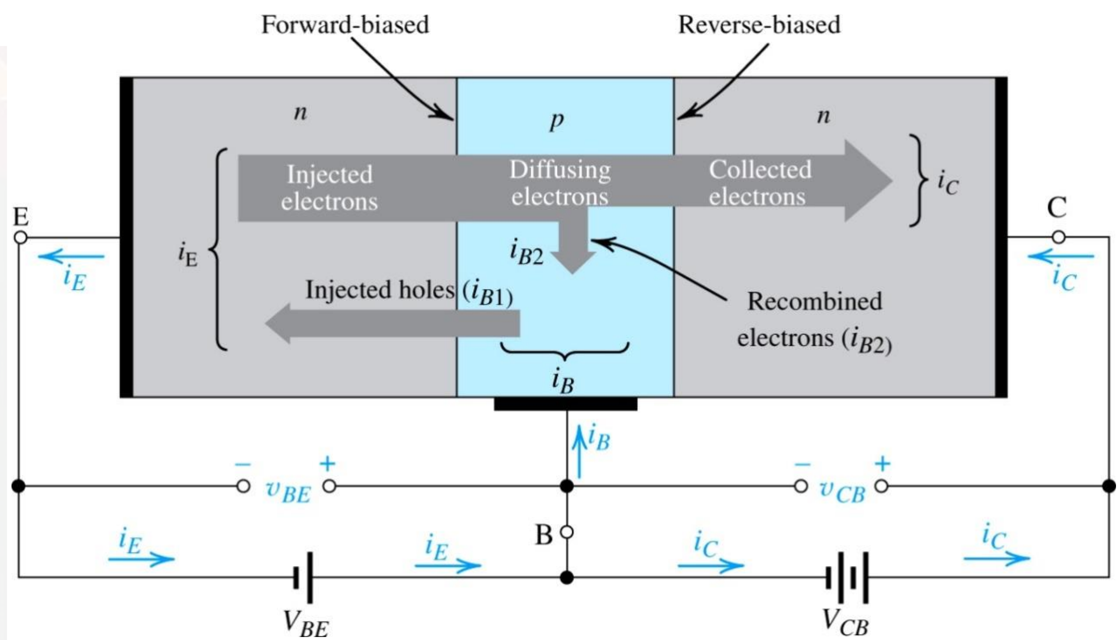


Figure 5.3: Current flow in an *npn* transistor biased to operate in the active mode. (Reverse current components due to drift of thermally generated minority carriers are not shown.)

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Current Flow

- Forward bias on emitter-base junction will cause current to flow.
- This current has two components:
  - electrons injected from emitter into base
  - holes injected from base into emitter.
- It will be shown that first (of the two above) is desirable.
  - This is achieved with heavy doping of emitter, light doping of base.

Current Flow

- **emitter current** (i_E) – is current which flows across EBJ
  - Flows "out" of emitter lead
- **minority carriers** – in *p*-type region.
  - These electrons will be injected from emitter into base.
  - Opposite direction.
- Because base is thin, concentration of excess minority carriers within it will exhibit constant gradient.

$\mathbf{n_p}(x)$=concentration of minority carriers a position x (where 0 represents EBJ boundary)
n_{p0}= thermal-equilibrium value of minority carrier (electron) concentration in base region
v_{BE} =voltage applied across base-emitter junction
V_T =thermal voltage (constant)

(eq5.1) $$\mathbf{n_p}(0) = n_{p0} e^{v_{BE}/V_T}$$

Straight line represents constant gradient.

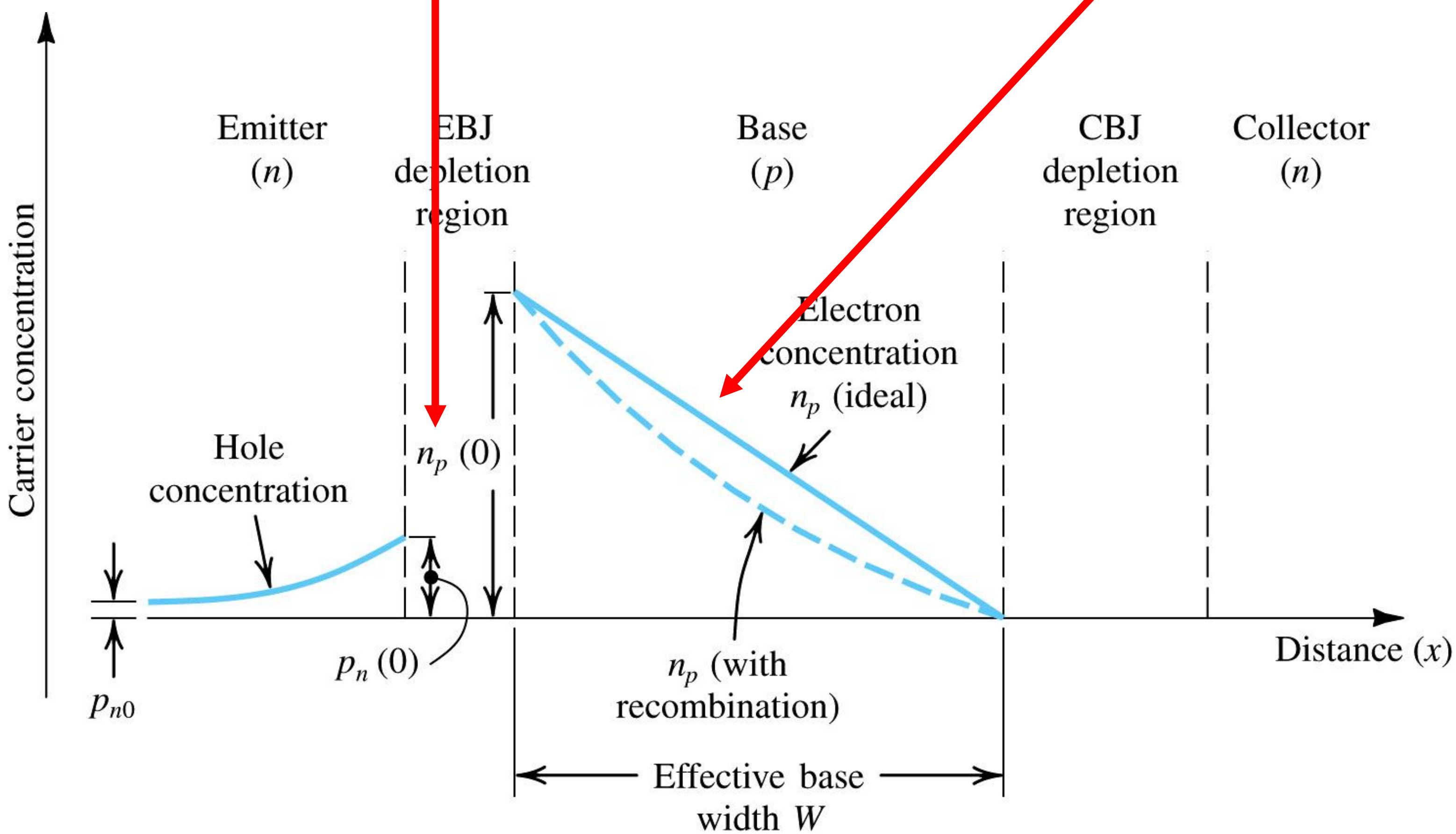

Figure 6.4 Profiles of minority-carrier concentrations in the base and in the emitter of an *npn* transistor operating in the active mode: $v_{BE} > 0$ and $v_{CB} \geq 0$.

Current Flow

- Concentration of minority carrier n_p at boundary EBJ is defined by (5.1).
- Concentration of minority carriers n_p at boundary of CBJ is zero.
  - Positive v_{CB} causes these electrons to be swept across junction.

$\mathbf{n_p}(x)$=concentration of minority carriers a position…
…x (where 0 represents EBJ boundary)
n_{p0} = thermal-equilibrium value of minority carrier…
…(electron) concentration in base region
v_{BE} =voltage applied across base-emitter junction
V_T =thermal voltage (constant)

$$\mathbf{n_p}(0) = n_{p0} e^{v_{BE}/V_T} \quad \text{(eq5.1)}$$

Current Flow

- Tapered minority-carrier concentration profile exists.
- It causes electrons injected into base to diffuse through base toward collector.
- As such, electron diffusion current (I_n) exists.

A_E =cross-sectiona area of the base-emitter junction
q= magnitude of the electron charge
D_n= electron diffusivity in base
W= width of base

$$\text{(eq5.2)} \quad I_n = \overbrace{A_E q D_n \frac{dn_p(x)}{dx}}$$

$$\text{(eq5.2)} \quad I_n = A_E q D_n \underbrace{\left(\frac{-dn_p(0)}{W} \right)}_{\text{this simplification may be made if gradient assumed to be straight line}}$$

Current Flow

- Some “diffusing” electrons will combine with holes (majority carriers in base).
- Base is thin, however, and recombination is minimal.
- Recombination does, however, cause gradient to take slightly curved shape.
  - The straight line is assumed.

$\mathbf{n_p}(x)$=concentration of minority carriers a position x (where 0 represents EBJ boundary)
n_{p0} = thermal-equilibrium value of minority carrier (electron) concentration in base region
v_{BE} =voltage applied across base-emitter junction
V_T =thermal voltage (constant)

(eq6.1) $\mathbf{n_p}(0) = n_{p0} e^{v_{BE}/V_T}$

Recombination causes actual gradient to be curved, not straight.

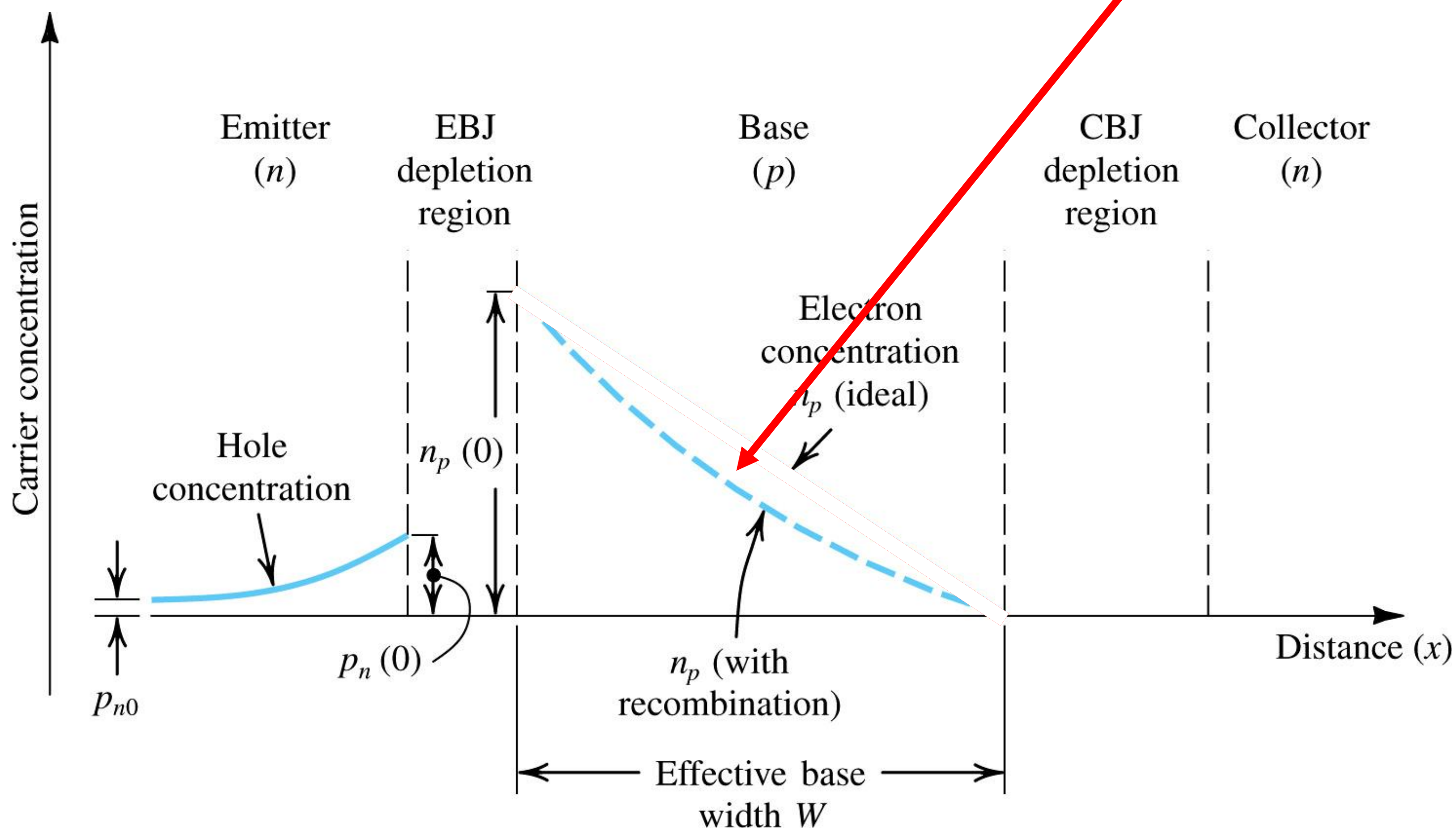

Figure 6.4 Profiles of minority-carrier concentrations in the base and in the emitter of an *npn* transistor operating in the active mode: $v_{BE} > 0$ and $v_{CB} \geq 0$.

The Collector Current

- It is observed that most diffusing electrons will reach boundary of collector-base depletion region.
- Because collector is more positive than base, these electrons are swept into collector.
  - **collector current (i_C)** is approximately equal to I_n.
  - $i_C = I_n$

(eq5.3) $i_C = I_S \mathbf{e}^{v_{BE}/V_T}$

saturation current: $I_S = \dfrac{A_E q D_n n_{p0}}{W}$

(eq5.4) $\underbrace{I_S = \dfrac{A_E q D_n}{W} \dfrac{n_i^2}{N_A}}$

ni= intrinsic carrier density
NA= doping concentration of base

The Collector Current

- Magnitude of i_C is independent of v_{CB}.
  - As long as collector is positive, with respect to base.
- **saturation current** (I_S) – is inversely proportional to W and directly proportional to area of EBJ.
  - Typically between 10^{-12} and $10^{-18} A$
  - Also referred to as **scale current**.

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The Base Current

- **base current (i_B)** – composed of two components:
  - i_{b1} – due to holes injected from base region into emitter.
  - i_{b2} – due to holes that have to be supplied by external circuit to replace those recombined.

(eq5.10) $$i_B = \underbrace{\frac{i_C}{\beta}}_{\beta = \text{transistor parameter}}$$

(eq5.11) $$i_B = \frac{I_S}{\beta}\mathbf{e}^{v_{BE}/V_T}$$

The Base Current

- **common-emitter current gain** (β) – is influenced by two factors:
  - width of base region (W)
  - relative doping of base emitter regions (N_A/N_D)
- High Value of β
  - thin base (small W in nano-meters)
  - lightly doped base / heavily doped emitter (small N_A/N_D)

The Emitter Current

- All current which enters transistor must leave.
  - $i_E = i_C + i_B$
- Equations (5.13) through (5.19) expand upon this idea.

this expression is generated through combination of (5.10) and 5.13

(eq5.14/5.15) $i_E = \frac{\beta+1}{\beta} i_C = \frac{\beta+1}{\beta} \underbrace{\left(I_S \mathbf{e}^{v_{BE}/V_T}\right)}_{i_C}$

(eq5.16) $i_C = \alpha i_E$

this parameter is reffered to as **common-base current gain**

(eq5.17) $\alpha = \frac{\beta}{\beta+1}$ (eq5.19) $\beta = \frac{\alpha}{1-\alpha}$

(eq5.18) $i_E = \frac{I_S}{\alpha} \mathbf{e}^{v_{BE}/V_T}$

Recapitulation and Equivalent-Circuit Models

- Previous slides present first-order BJT model.
  - Assumes *npn* transistor in active mode.
- Basic relationship is collector current (i_C) is related exponentially to forward-bias voltage (v_{BE}).
  - It remains independent of v_{CB} as long as this junction remains reverse biased.
    - $v_{CB} > 0$

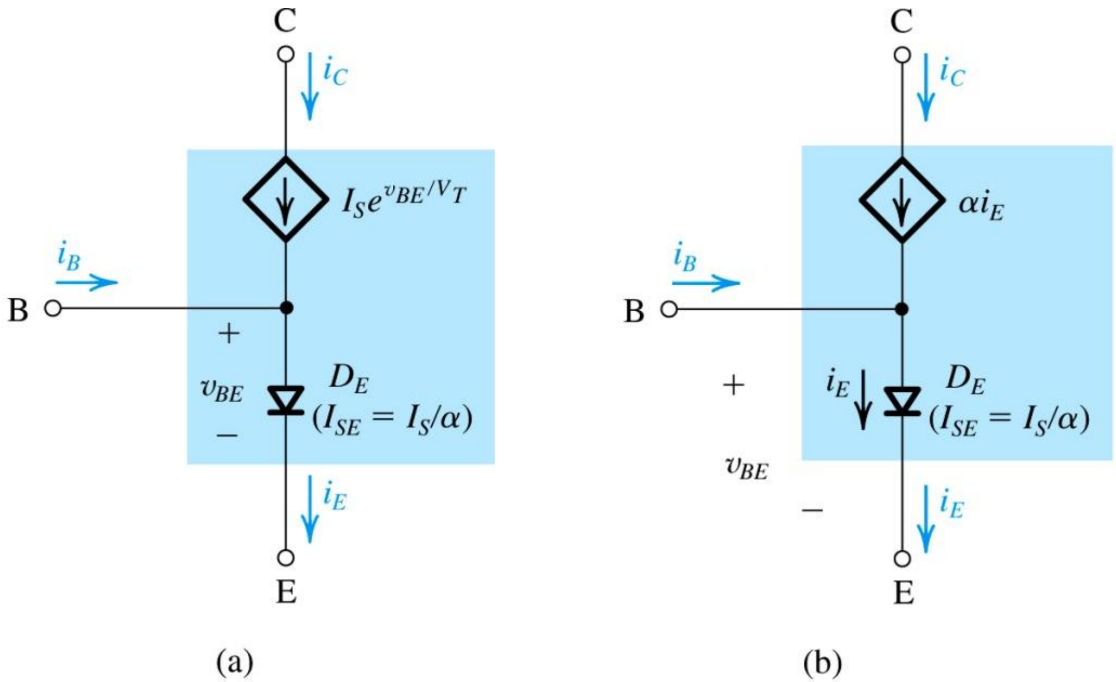


Figure 5.5: Large-signal equivalent-circuit models of the *npn* BJT operating in the forward active mode.

Two models of NPN transistor:

1. **Voltage Controlled Current Source**
   - iC proportional to exp (vBE) - **nonlinear**
   - Ideal diode DE between B and E.
   - Alphaf is forward active mode value close to 1.
2. **Current Controlled Current Source**

5.1.3. **Structure of Actual Transistors**

- Figure 5.6 shows a more realistic BJT cross-section.
- Collector virtually surrounds entire emitter region.
  - This makes it difficult for electrons injected into base to escape collection.
- Device is not symmetrical.
  - As such, emitter and collector cannot be interchanged.
  - Device is uni-directional.

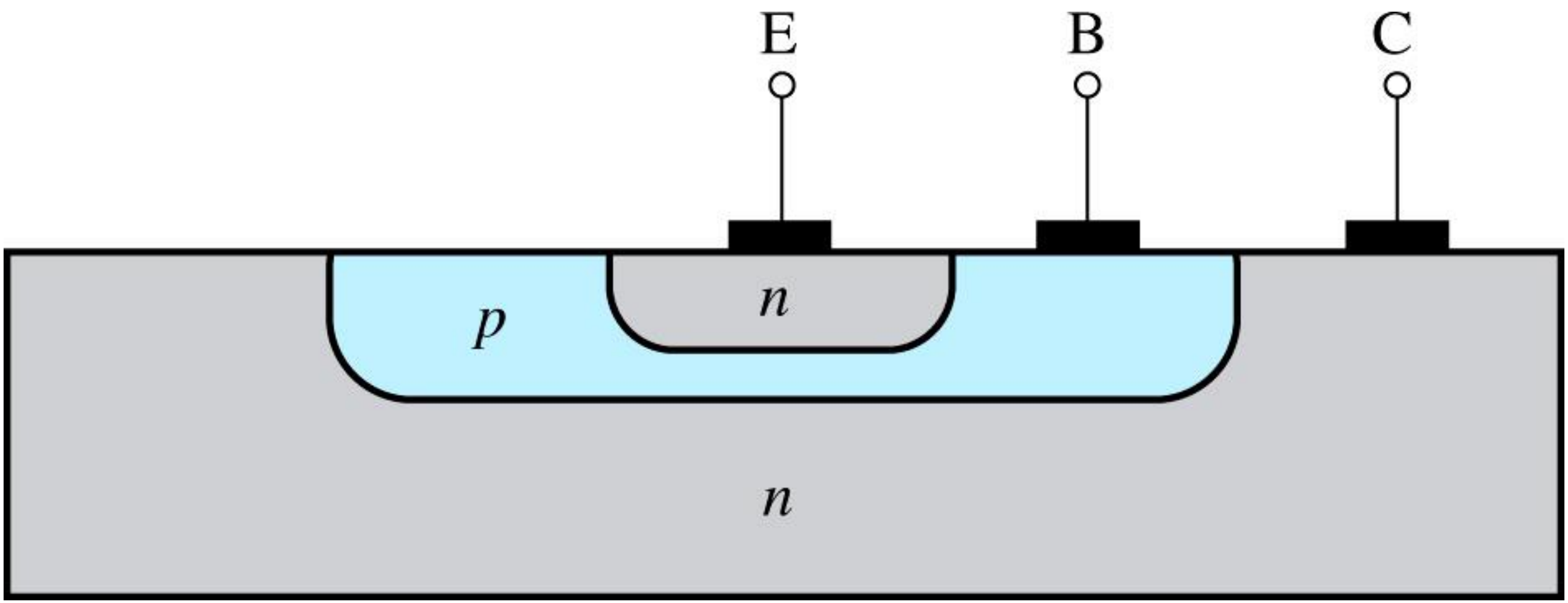
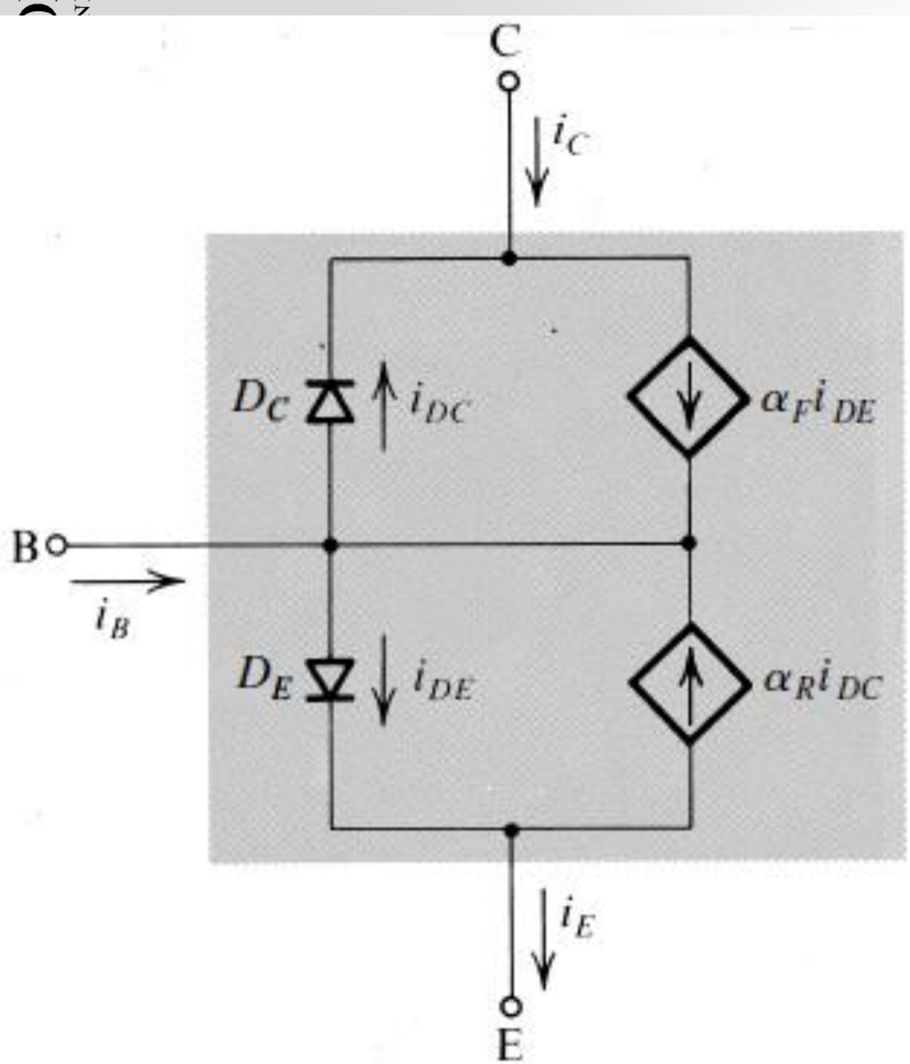


Figure 5.6: Cross-section of an *npn* BJT.

EBERS MOLL (EM) MODEL FOR BJT



1. This is combination of two models – forward and reverse useful to predict behavior in all modes.
2. Diode Dc and ccs alphaR iDC
3. Diode DE and ccs alphaF iDE

EBERS MOLL (EM) MODEL FOR BJT

- EM model gives more accurate estimates of terminal currents - iC, iB and iE using two components – forward mode and reverse mode currents.

- In forward active mode, when vCB >0, the leakage current in reversed CB junction are very small and can be neglected leading to original current equations.

5.1.5. Operation in Saturation Mode

iC - vCB characteristics when NPN driven by a cc source in emitter

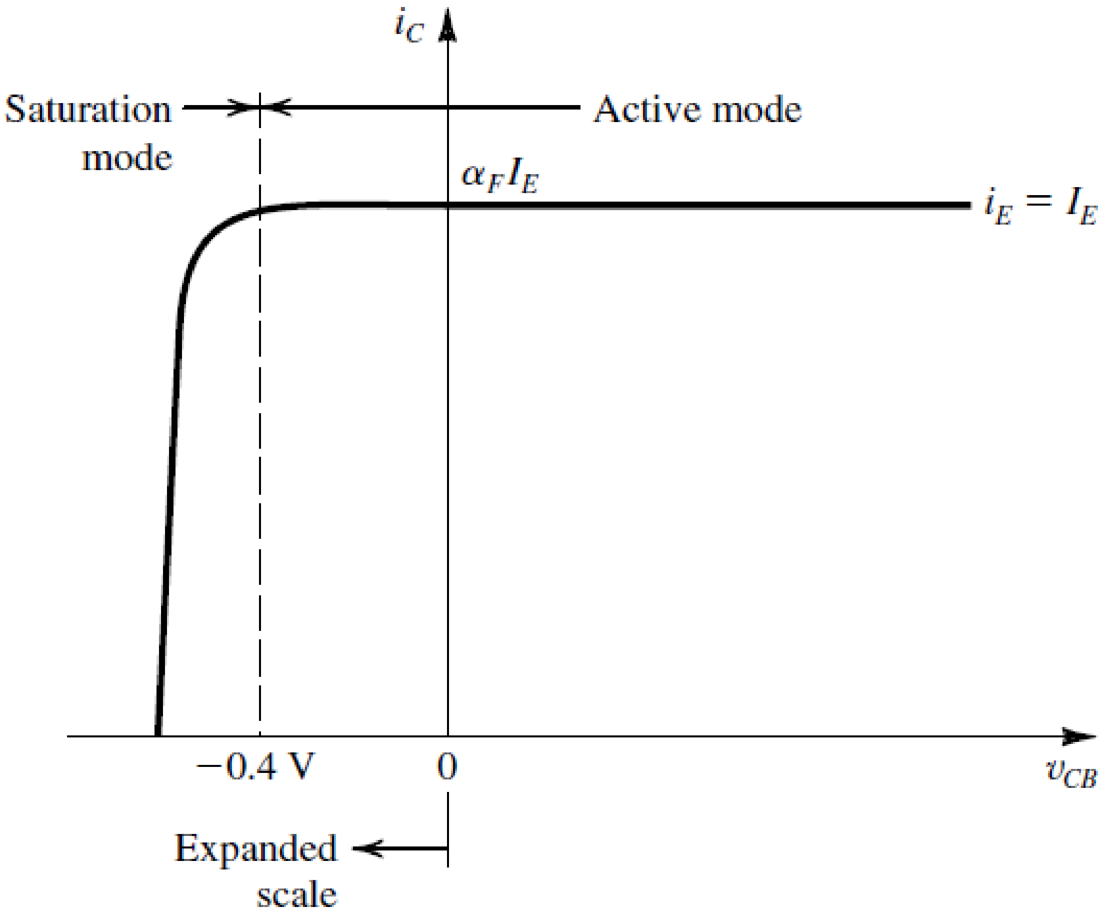
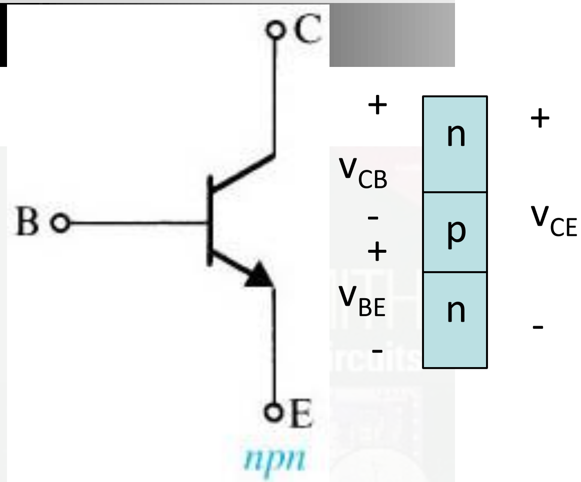


FIGURE 5.9 The i_C–v_{CB} characteristic of an *npn* transistor fed with a constant emitter current I_E. The transistor enters the saturation mode of operation for $v_{CB} < -0.4$ V, and the collector current diminishes.

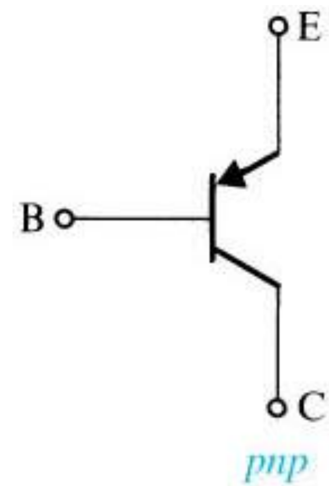
- For vCB > -0.4V, the BJT is in active mode.
- iC is alphaF times current source value.
- As CB becomes forward biased, vCB falls below -0.4V, it reaches saturation.

Circuit Symbols

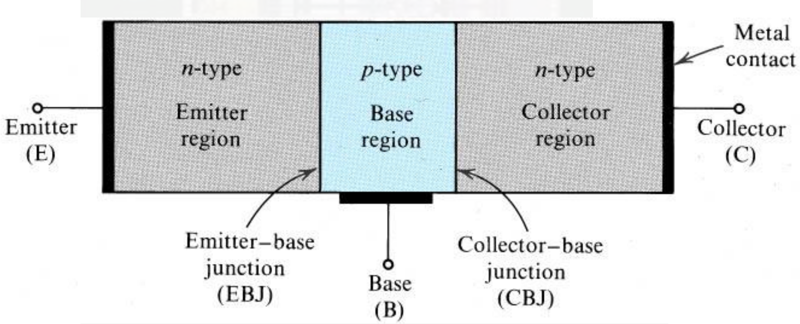
The arrow is at the emitter, and it points to the n-type region. In the npn, the emitter is n type; in the pnp, the base is n-type.

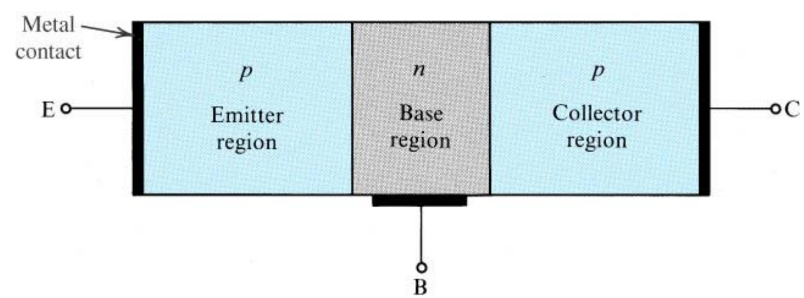


(a)



(b)





5.1.5. **The *pnp* Transistor**

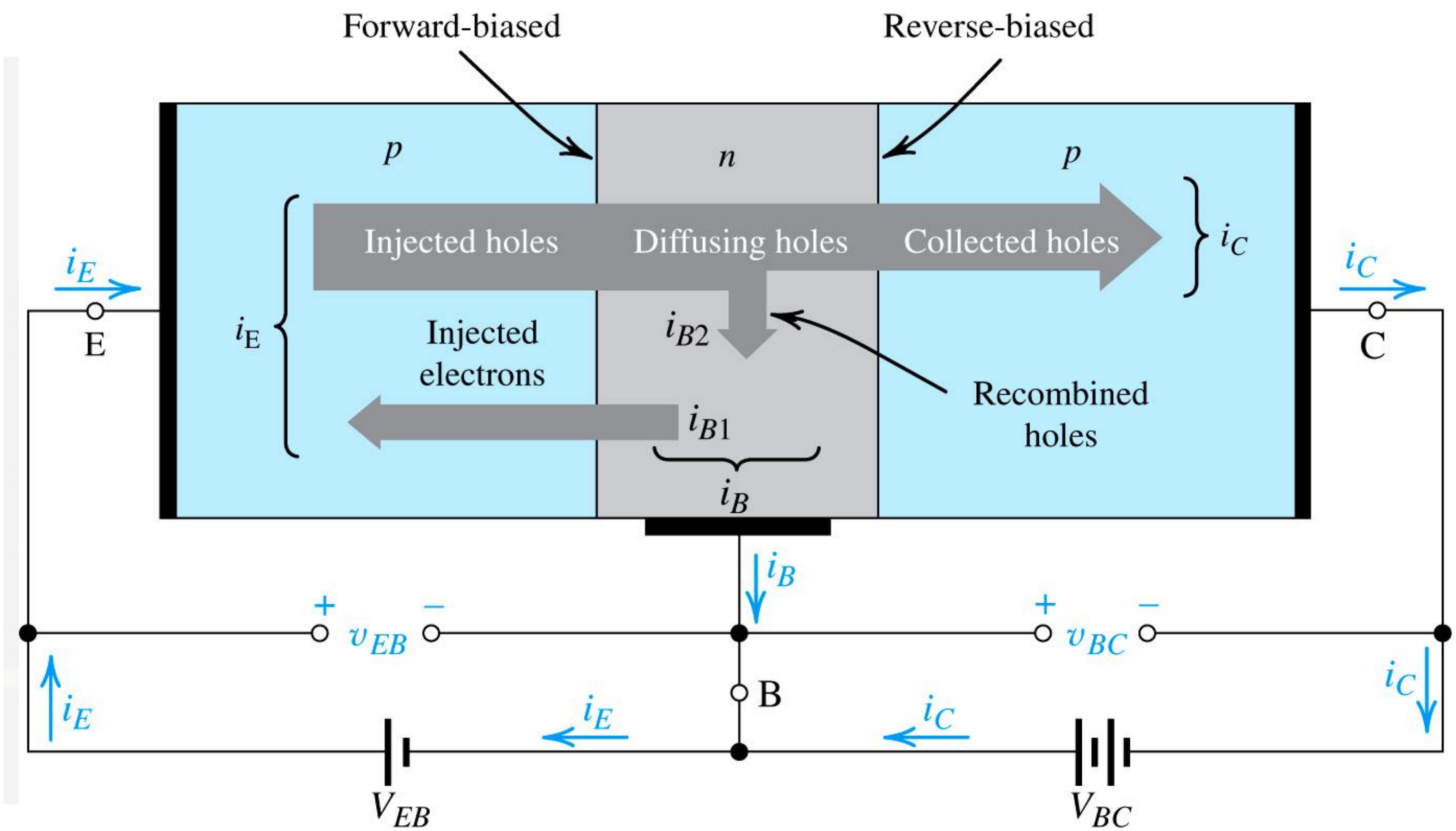


Figure 5.10: Current flow in a *pnp* transistor biased to operate in the active mode.

Microelectronic Circuits by Adel S. Sedra and Kenneth C. Smith (0195323033)

5.1.5. The *pnp* Transistor

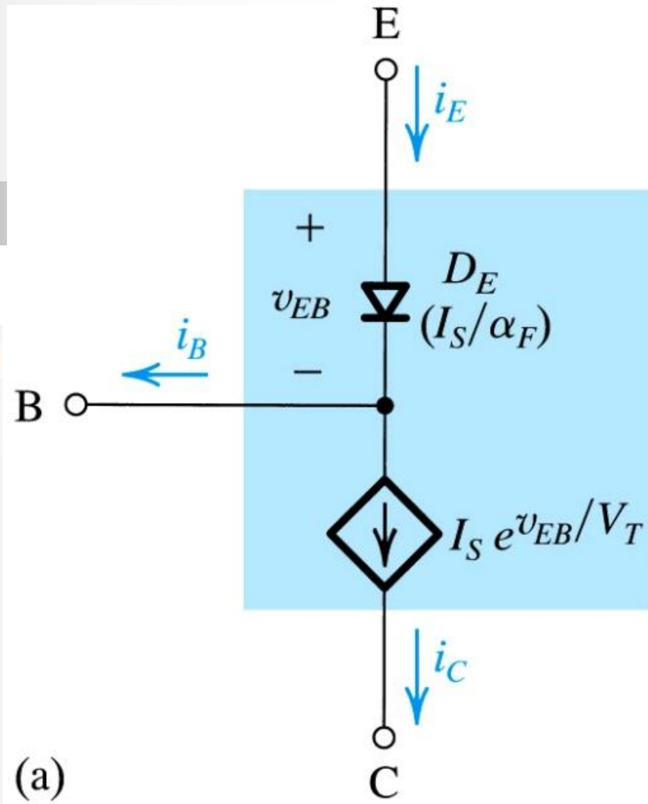


Figure 5.11: Large-signal models for the *pnp* transistor operating in the active mode.

5.2. **Current-Voltage Characteristics**

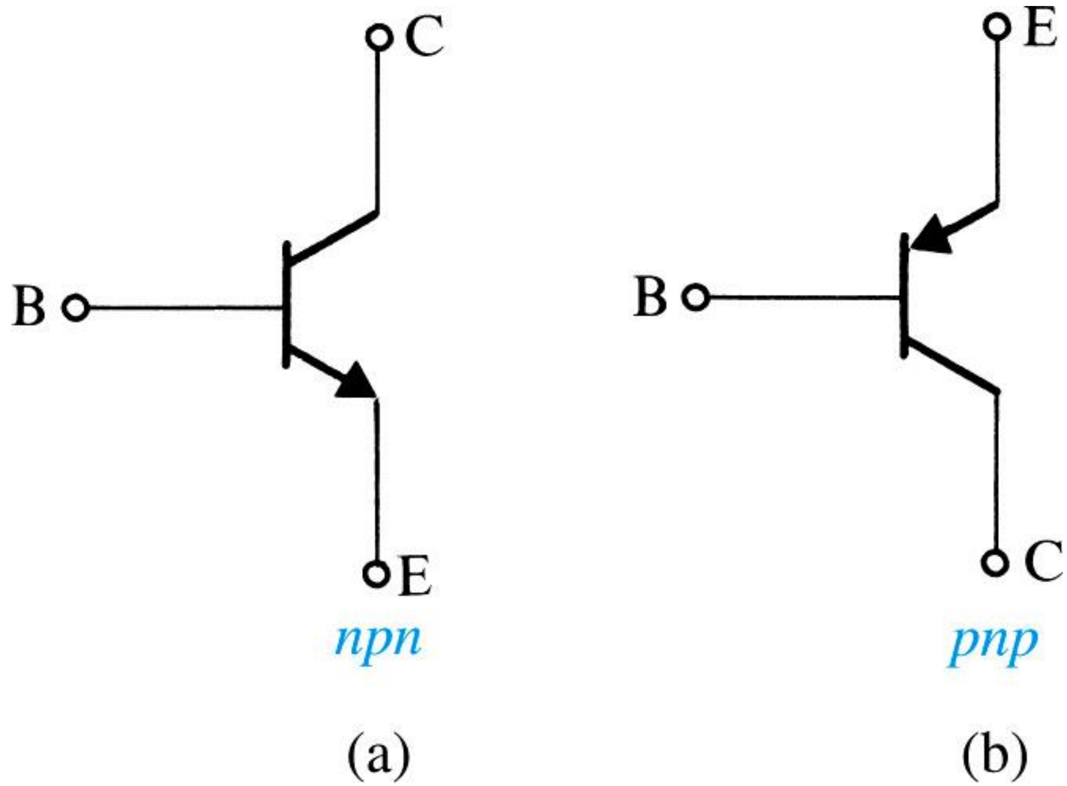


Figure 5.12: Circuit symbols for BJTs.

5.2.1. **Circuit Symbols and Conventions**

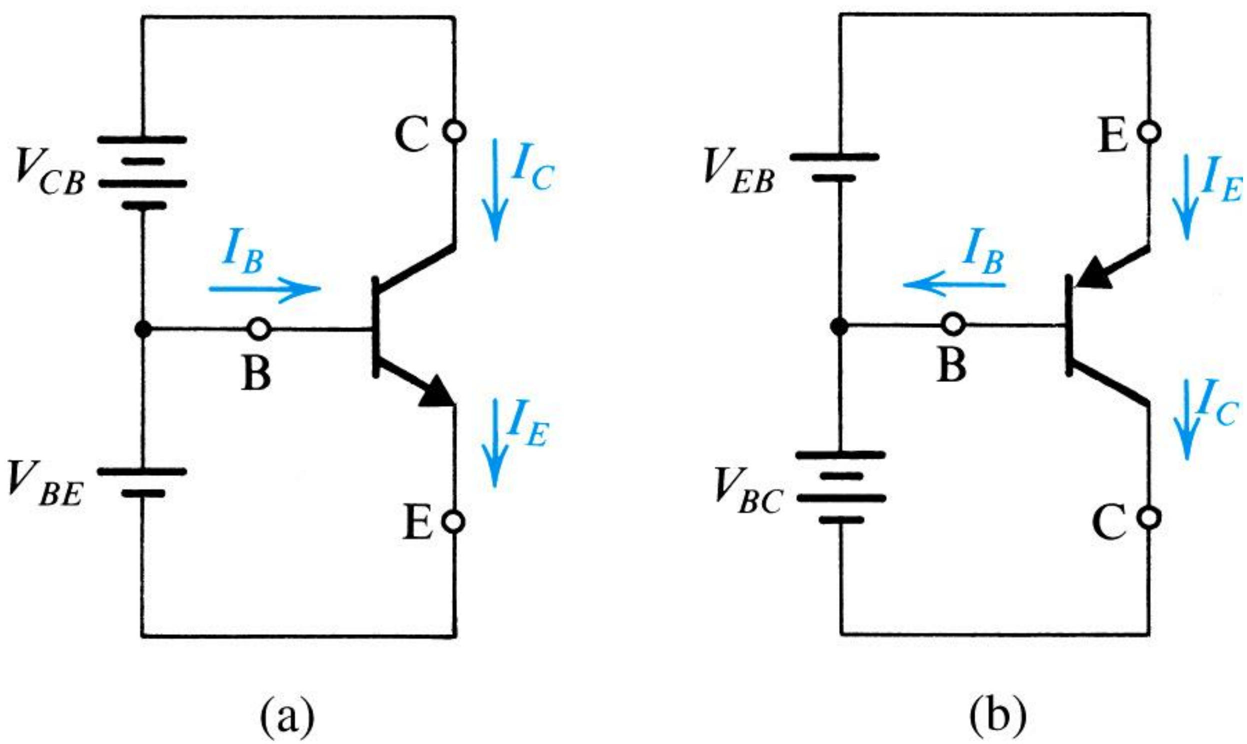


Figure 5.13: Voltage polarities and current flow in transistors biased in the active mode.

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5.2.1. **Circuit Symbols and Conventions**

Table 6.2 Summary of the BJT Current–Voltage Relationships in the Active Mode

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

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

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

Note: For the *pnp* transistor, replace v_{BE} with v_{EB}.

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

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

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

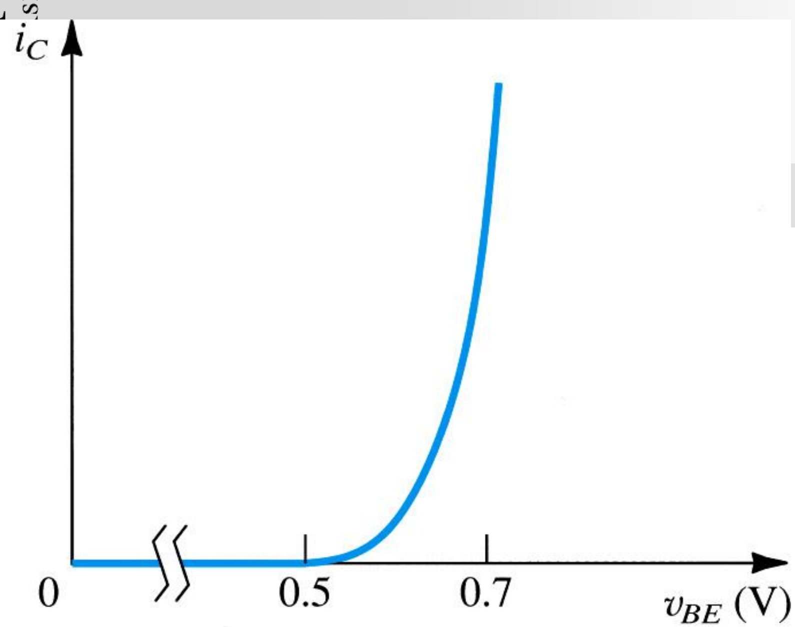
V_T = thermal voltage = $\dfrac{kT}{q} \simeq 25\ \text{mV}$ at room temperature

The Collector-Base Reverse Current (I_{CB0})

- Previously, small reverse current was ignored.
  - This is carried by thermally-generated minority carriers.
- However, it does deserve to be addressed.
- The **collector-base junction current** (I_{CBO}) is normally in the nano-ampere range.
  - Many times higher than its theoretically-predicted value.
  - I_{CBO} doubles for every 10 C rise in temperature.

5.2.2. **Graphical Representation of Transistor Characteristics**

The Common – Base Characteristics



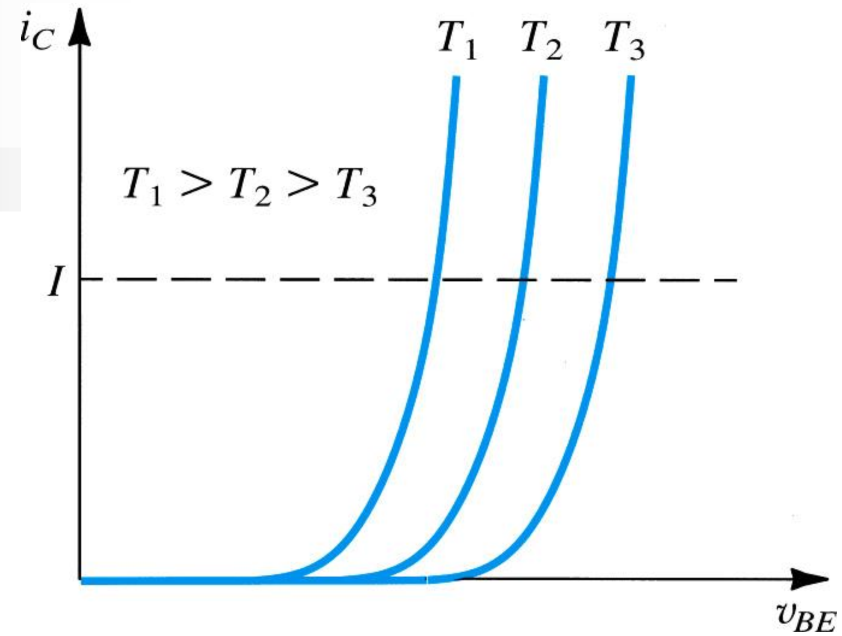


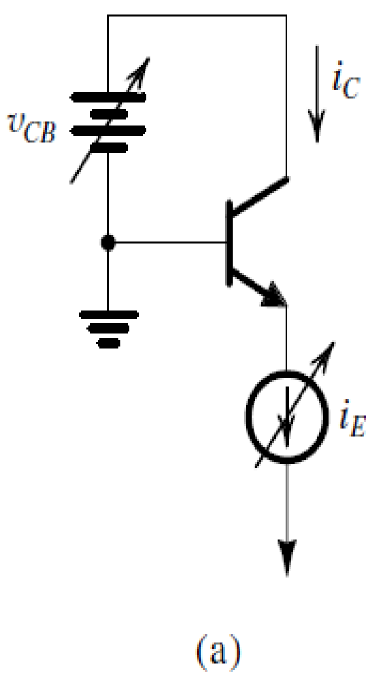
Figure 5.15/15: (left) The i_C-v_{BE} characteristic for an npn transistor. **(right)** Effect of temperature on the i_C-v_{BE} characteristic. Voltage polarities and current flow in transistors biased in the active mode.

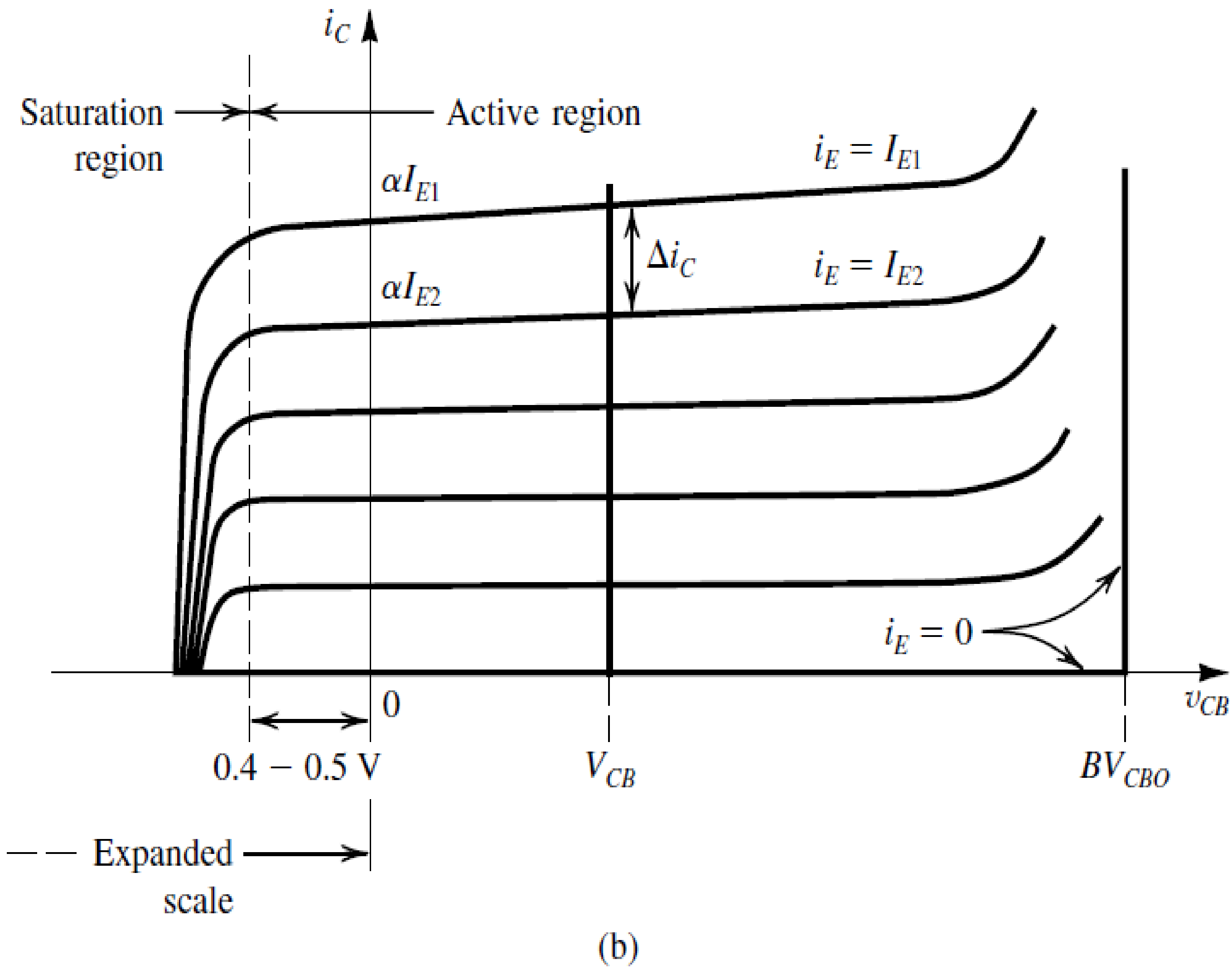
VBE decreases by about 2 m V for each rise of 1° C in temperature.

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

For pnp transistor V_{BE} should be replaced with V_{EB}

iC - vCB characteristics when NPN driven by a cc source in emitter





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5.2.3. **Dependence of i_C on Collector Voltage – The Early Effect**

- When operated in active region, practical BJT's show some dependence of collector current on collector voltage.
- As such, i_C-v_{CB} characteristic is not "straight".

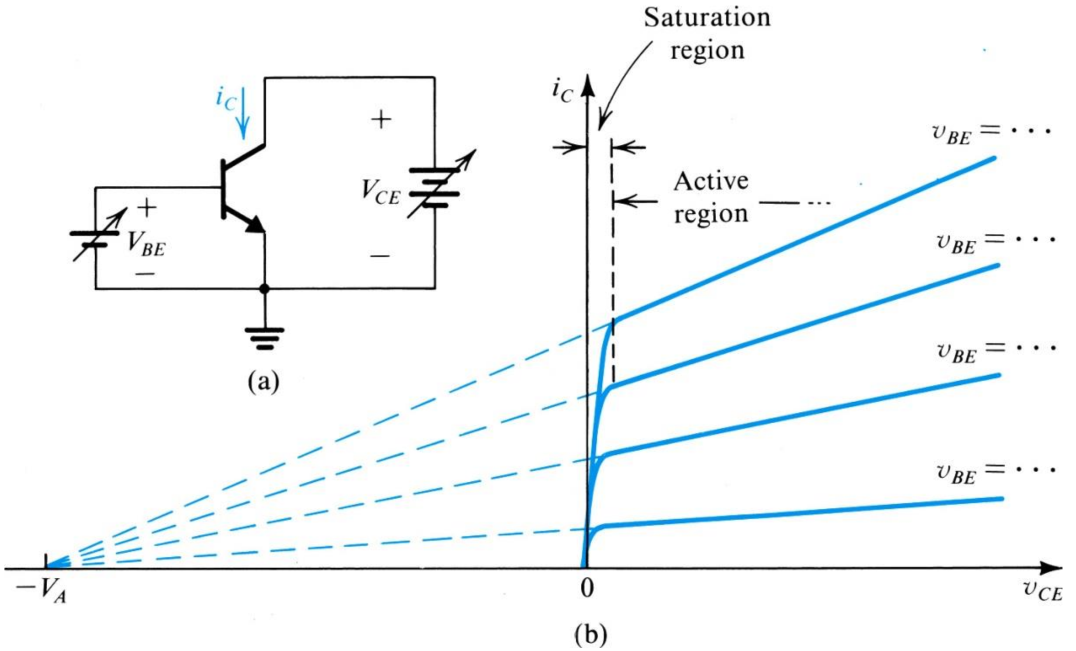


Figure 6.17 (a) Conceptual circuit for measuring the i_C–v_{CE} characteristics of the BJT. **(b)** The i_C–v_{CE} characteristics of a practical BJT.

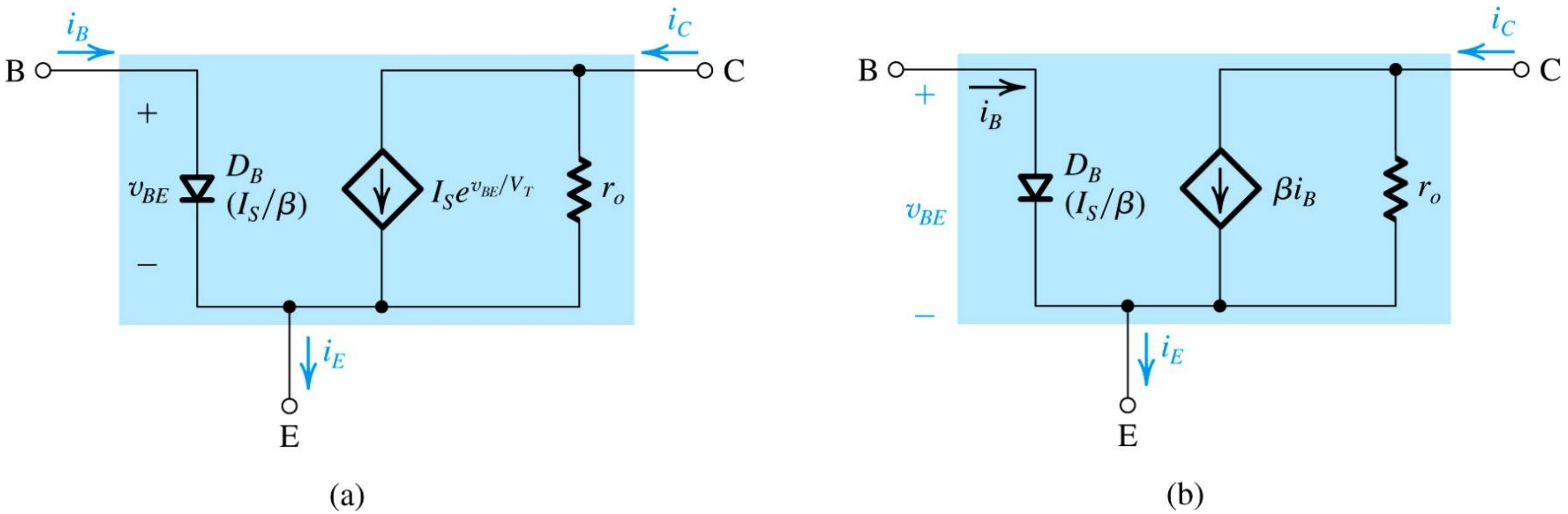


Figure 5.18: Large-signal equivalent-circuit models of an *npn* BJT operating in the active mode in the common-emitter configuration with the output resistance r_o included.

5.2.4. An Alternative Form of the Common-Emitter Characteristics

- The Common-Emitter Current Gain
  - A second way to quantify β is changing base current by Δi_B and measuing incremental Δi_C.
- The Saturation Voltage V_{CEsat} and Saturation Resistance

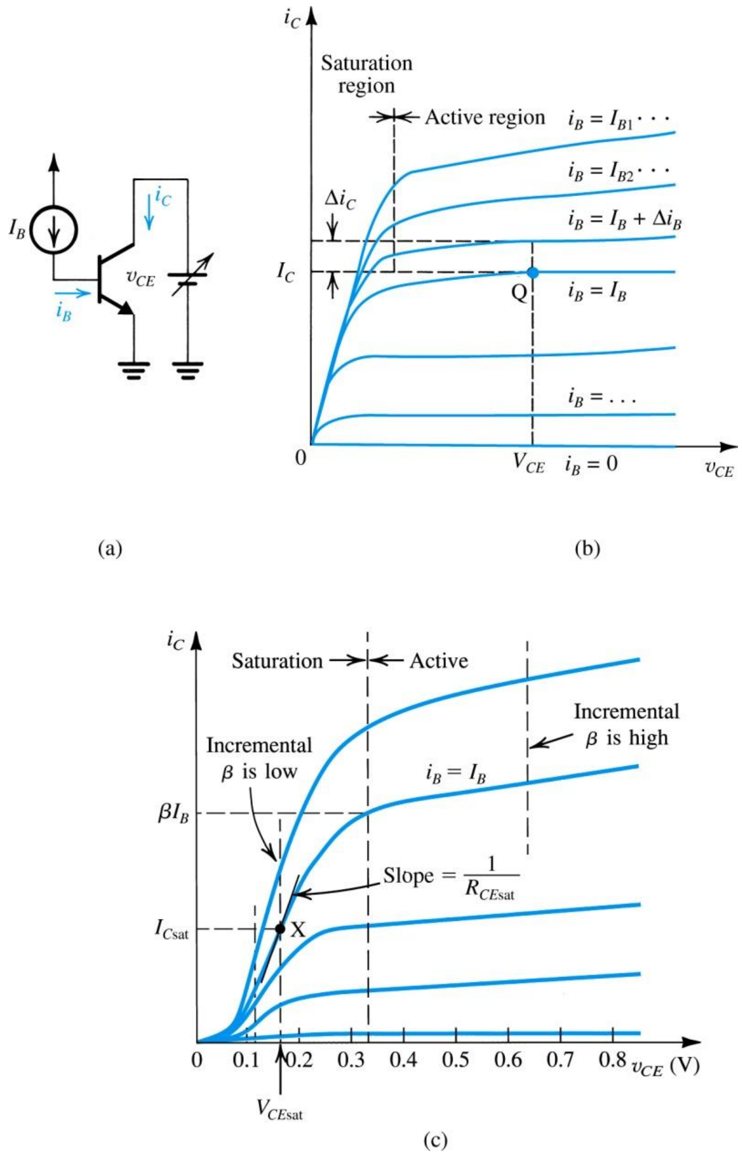


Figure 5.19: Common-emitter characteristics. (**a**) Basic CE circuit; note that in (**b**) the horizontal scale is expanded around the origin to show the saturation region in some detail. A much greater expansion of the saturation region is shown in (**c**).

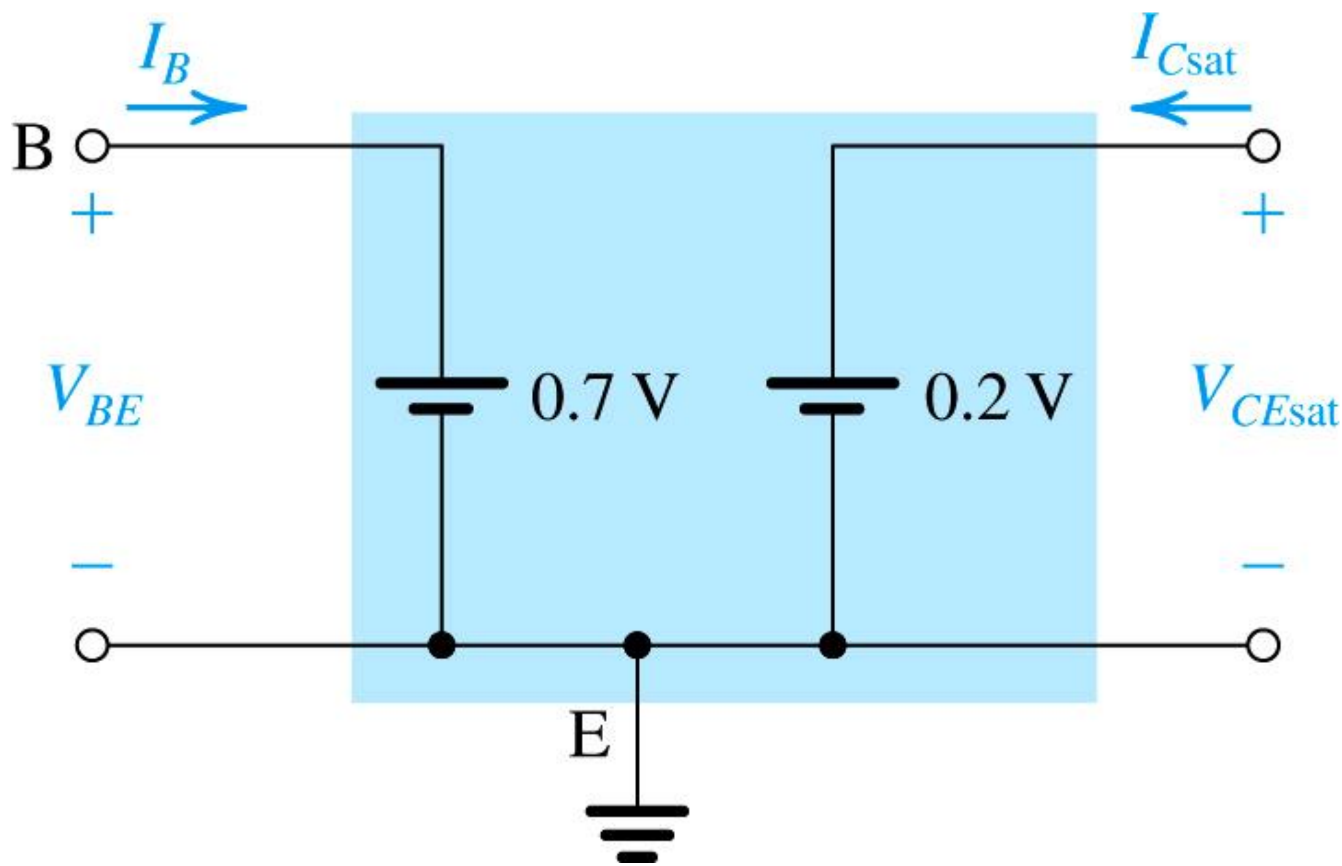


Figure 5.20: A simplified equivalent-circuit model of the saturated transistor.

BJT behavior in saturation

1. In active region, we assumed beta to be a constant depending upon transistor geometry and construction. Beta is ratio of iC/iB and has a value between 50 to 500.
2. As the BJT enters saturation, beta falls drastically as iC becomes less than (beta * iB). This beta is called as FORCED BETA which is less than beta.
3. The ratio of Beta to Forced Beta is called OVERDRIVE Factor.

BJT behavior in saturation

4. In saturation, the curve is nearly vertical showing behavior like a voltage source of voltage 0.2V to 0.4V with nearly zero source resistance.
5. Since the curve is sloping it gives a small resistance called

$R_{CE\ sat} = v_{CE} / i_C$ (when $i_c = i_{CEsat}$)

This is usually of the order of tens of ohms.

Example 5.1.

The transistor in the circuit of Fig. 5.15(a) has $\beta = 100$ and exhibits a v_{BE} of 0.7 V at $i_C = 1$ mA. Design the circuit so that a current of 2 mA flows through the collector and a voltage of +5 V appears at the collector.

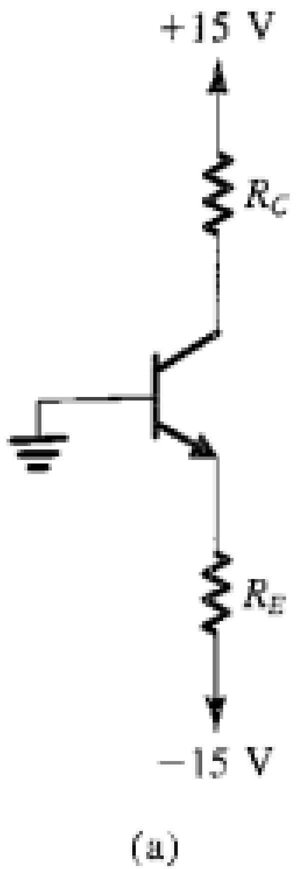
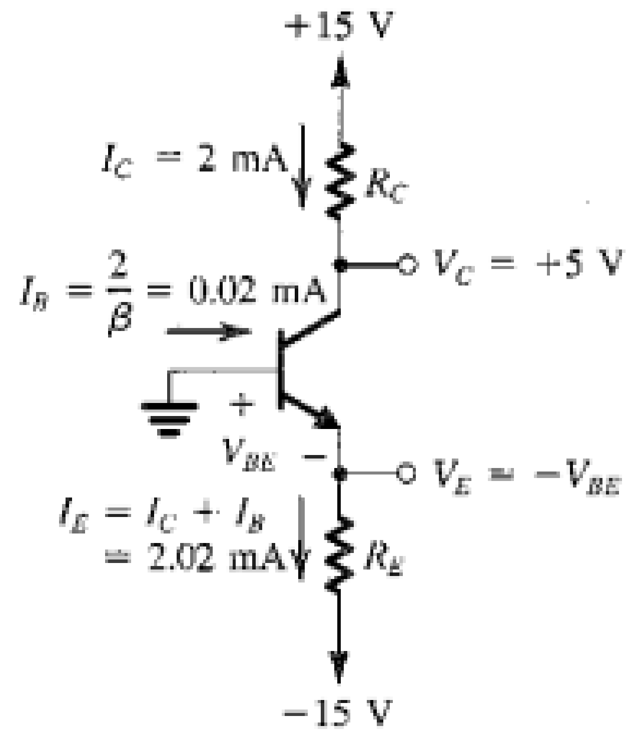


FIGURE 5.15 Circuit for Example 5.1.

Solution

Refer to Fig. 5.15(b). We note at the outset that since we are required to design for $V_C = +5$ V, the CBJ will be reverse biased and the BJT will be operating in the active mode. To obtain a voltage $V_C = +5$ V the voltage drop across R_C must be $15 - 5 = 10$ V. Now, since $I_C = 2$ mA, the value of R_C should be selected according to

$$R_C = \frac{10\text{ V}}{2\text{ mA}} = 5\text{ k}\Omega$$



Since $v_{BE} = 0.7$ V at $i_C = 1$ mA, the value of v_{BE} at $i_C = 2$ mA is

$$V_{BE} = 0.7 + V_T \ln\left(\frac{2}{1}\right) = 0.717\text{ V}$$

Since the base is at 0 V, the emitter voltage should be

$$V_E = -0.717\text{ V}$$

For $\beta = 100$, $\alpha = 100/101 = 0.99$. Thus the emitter current should t

$$I_E = \frac{I_C}{\alpha} = \frac{2}{0.99} = 2.02\text{ mA}$$

Now the value required for R_E can be determined from

$$R_E = \frac{V_E - (-15)}{I_E}$$

$$= \frac{-0.717 + 15}{2.02} = 7.07\text{ k}\Omega$$

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5.4. **Applying the BJT in Amplifier Design**

- Similar to the configuration presented in Chapter 5, an amplifier may be designed by transistor and series resistance.
- However, it is necessary to model the **voltage transfer characteristic** (VTC).
  - Equation (5.25)
- Appropriate biasing is important to ensure linear gain, and appropriate input voltage swing.
  - Small-signal model is employed to model the amp’s operation.

$$v_O = v_{CE} = V_{CC} - R_C i_C$$

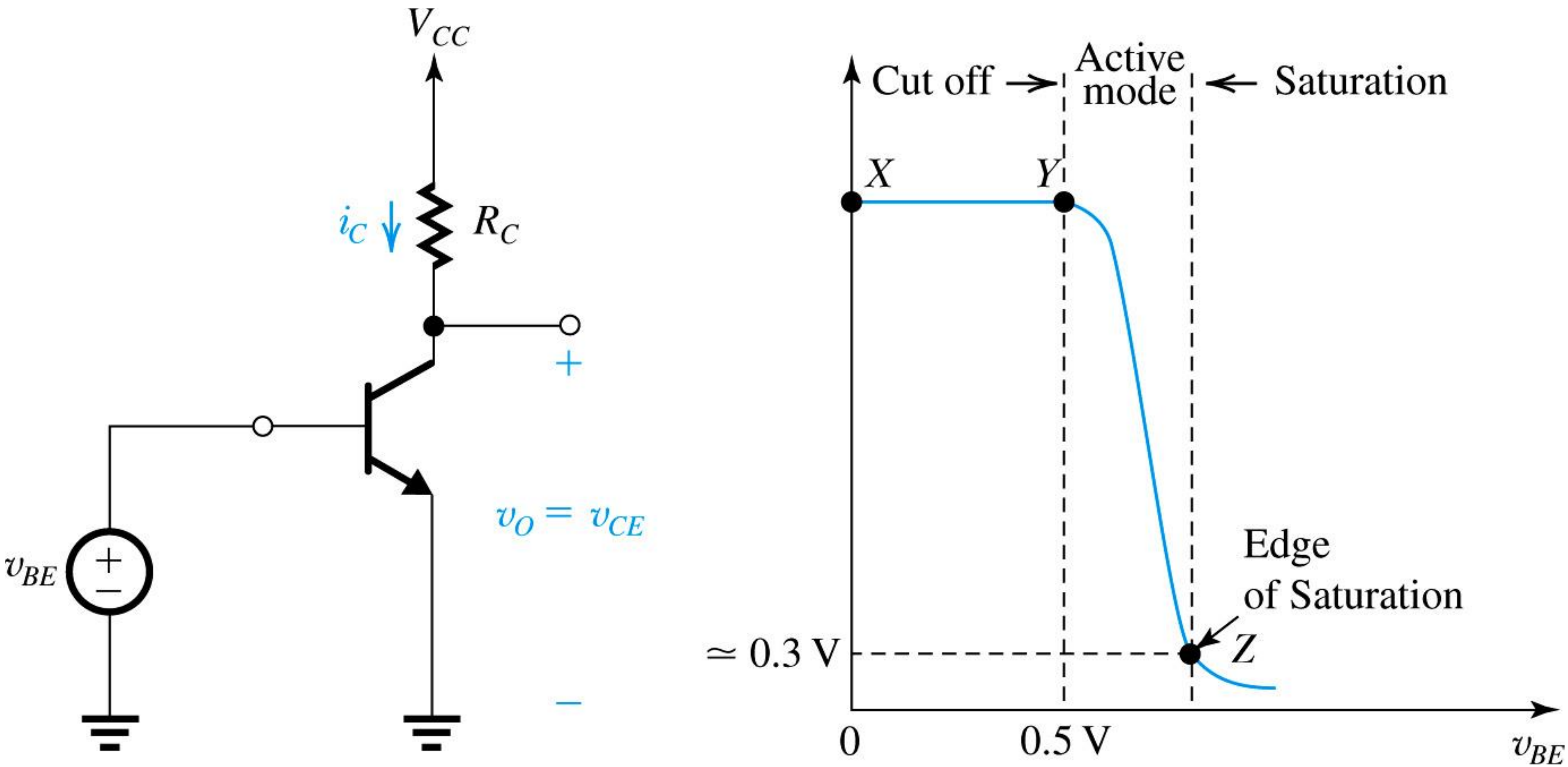


Figure 6.31 (a) Simple BJT amplifier with input v_{BE} and output v_{CE}. **(b)** The voltage transfer characteristic (VTC) of the amplifier in **(a)**. The three segments of the VTC correspond to the three modes of operation of the BJT.

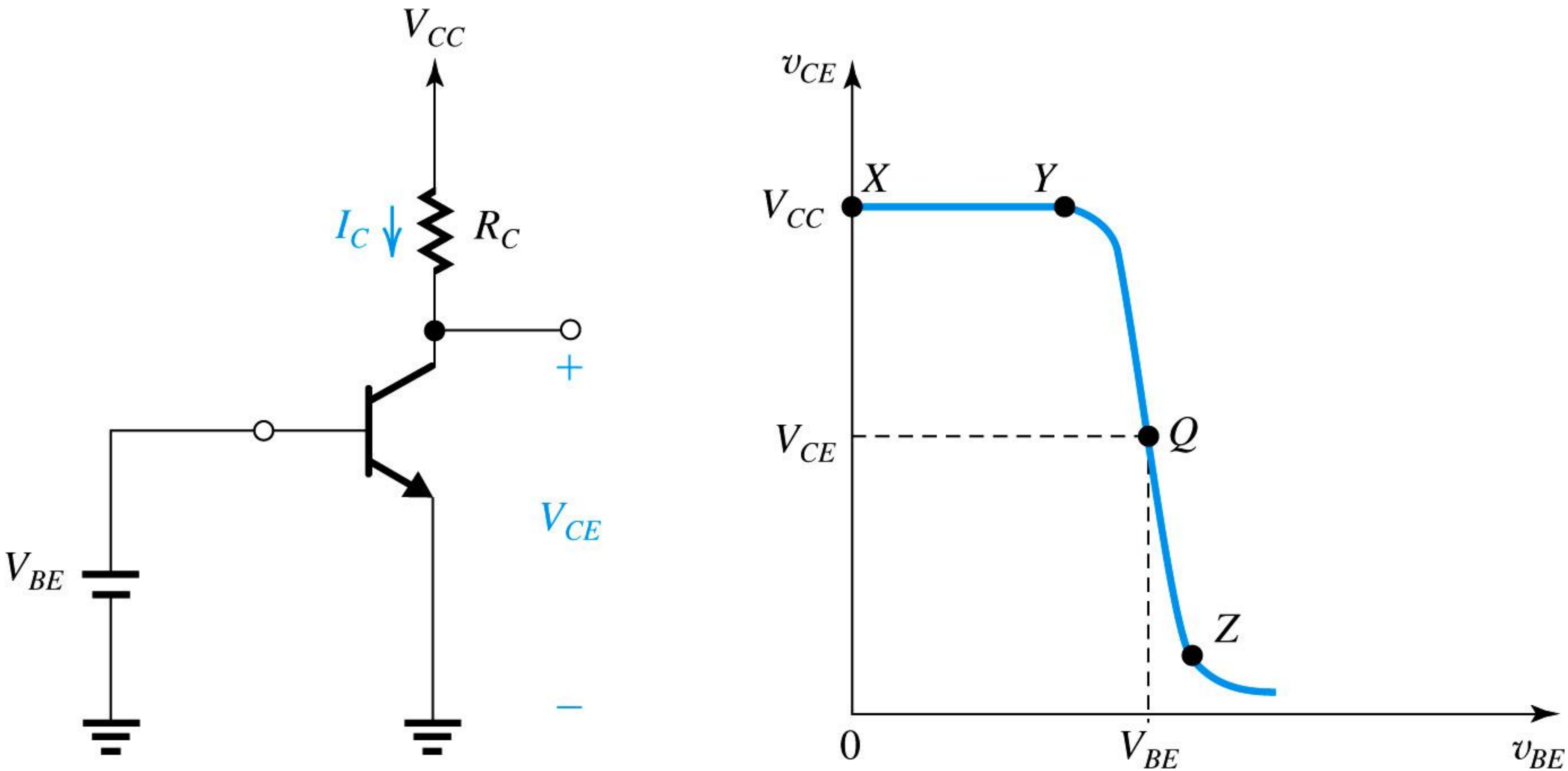
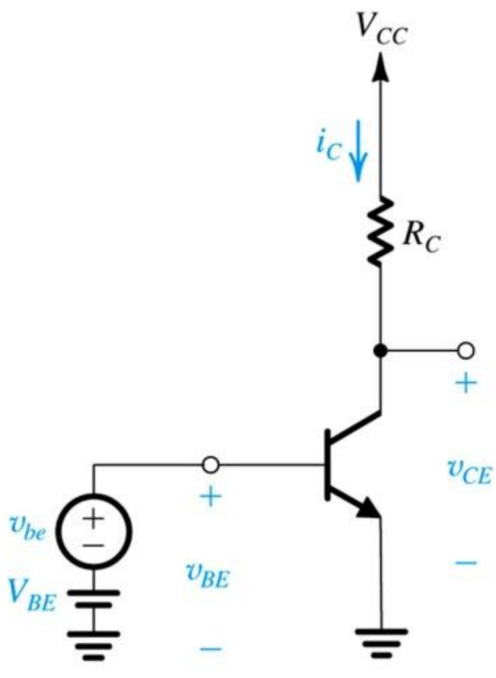


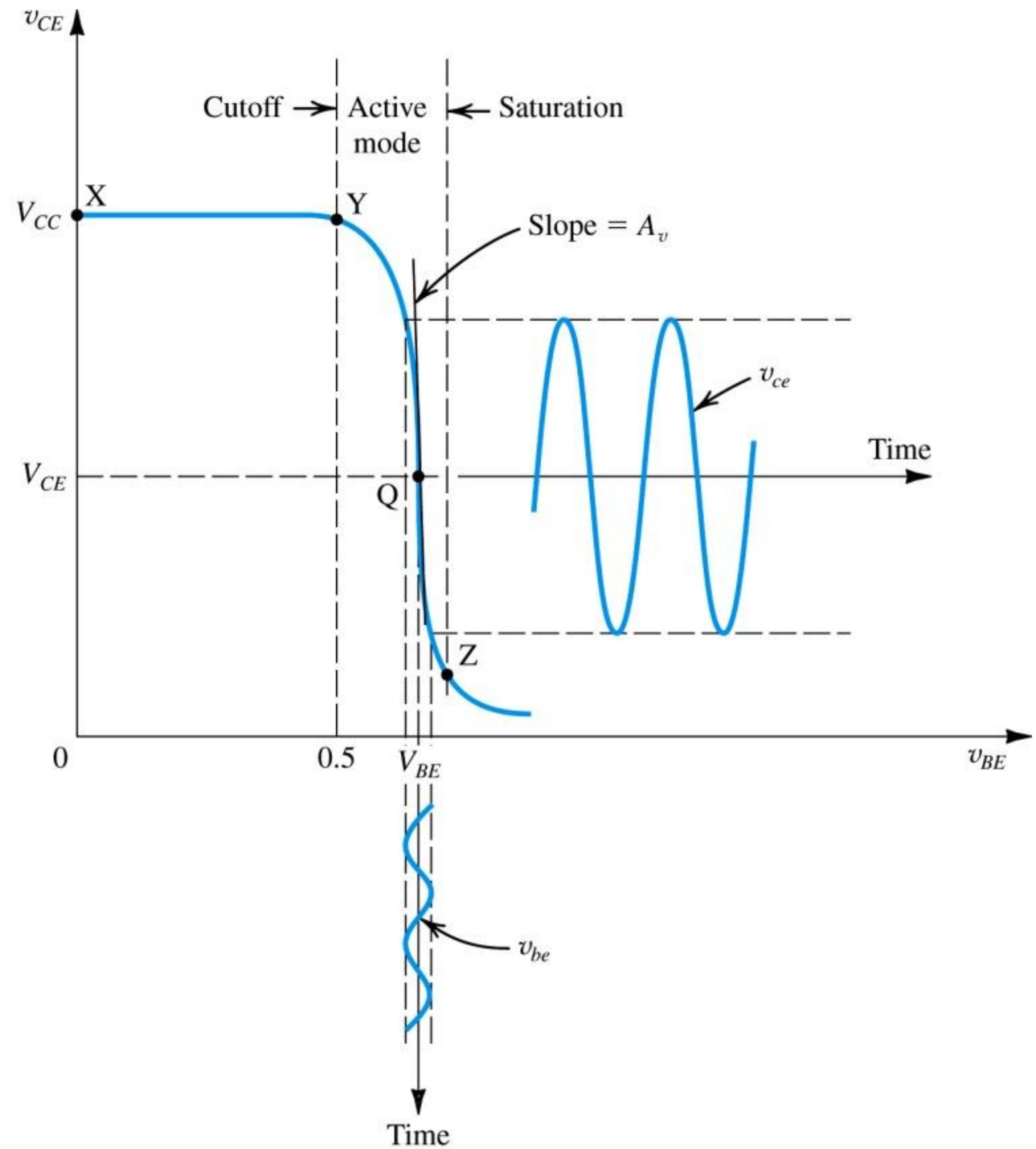
Figure 5.32: Biasing the BJT amplifier at a point Q located on the active-mode segment of the VTC.

$$A_v = -\frac{V_{CC} - V_{CE\text{sat}}}{V_T}$$

$$A_{v\max} \cong -\frac{V_{CC}}{V_T}$$



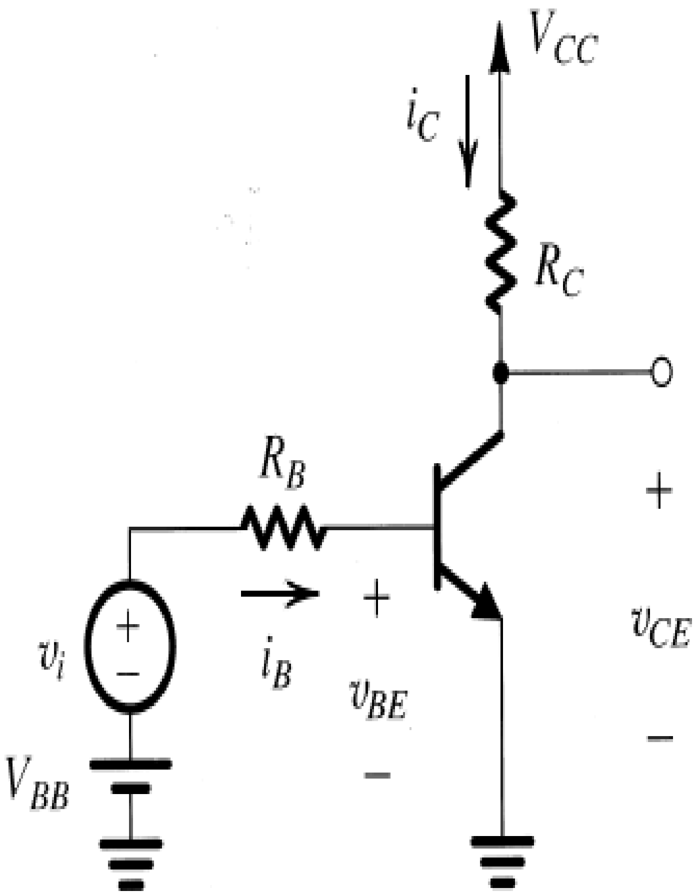
(a)



(b)

Figure 6.33 BJT amplifier biased at a point Q, with a small voltage signal v_{be} superimposed on the dc bias voltage V_{BE}. The resulting output signal v_{ce} appears superimposed on the dc collector voltage V_{CE}. The amplitude of v_{ce} is larger than that of v_{be} by the voltage gain A_v.

Determination of Quiescent Point Graphically



Quiescent Point or Q-point is the point plotted on vCE vs. iC characteristics based on output DC conditions namely iC and vCE.

First calculate input current iB and then derive iC and vCE from it.

Note input is AC + DC

Determination of Input parameters

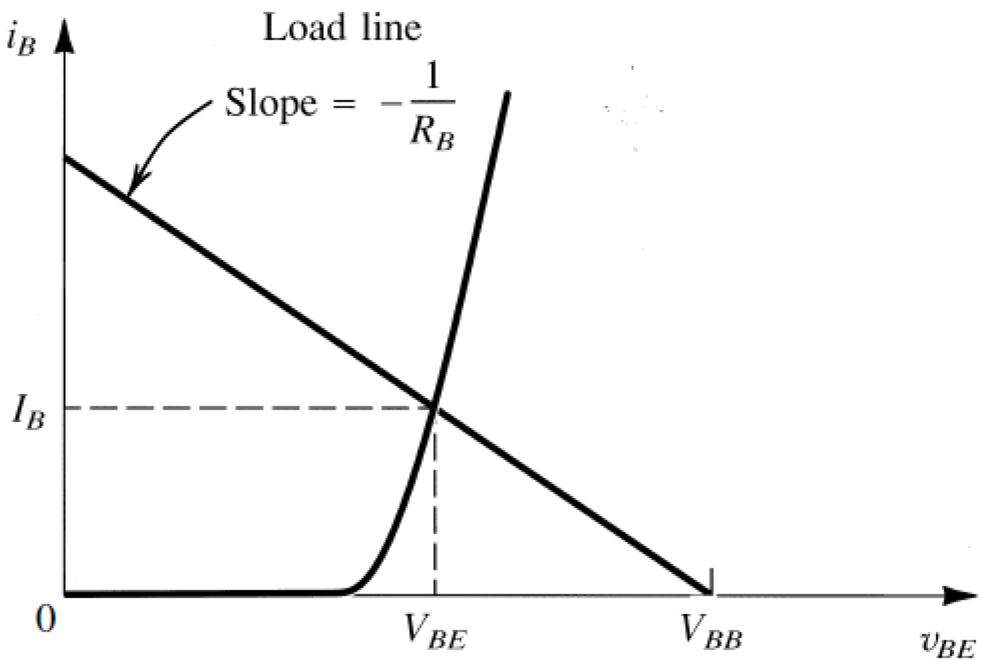


FIGURE 3.28 Graphical construction for the determination of

Note the iB vs. vBE characteristics. It has an exponential relationship of a diode. On this curve we plot equation of a straight line made by linear model:

VBB – vBE– iB * Rb = 0.

This equation has a slope of -1/RB. The point where it cuts the curve is Q-Point.

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Determination of Output parameters

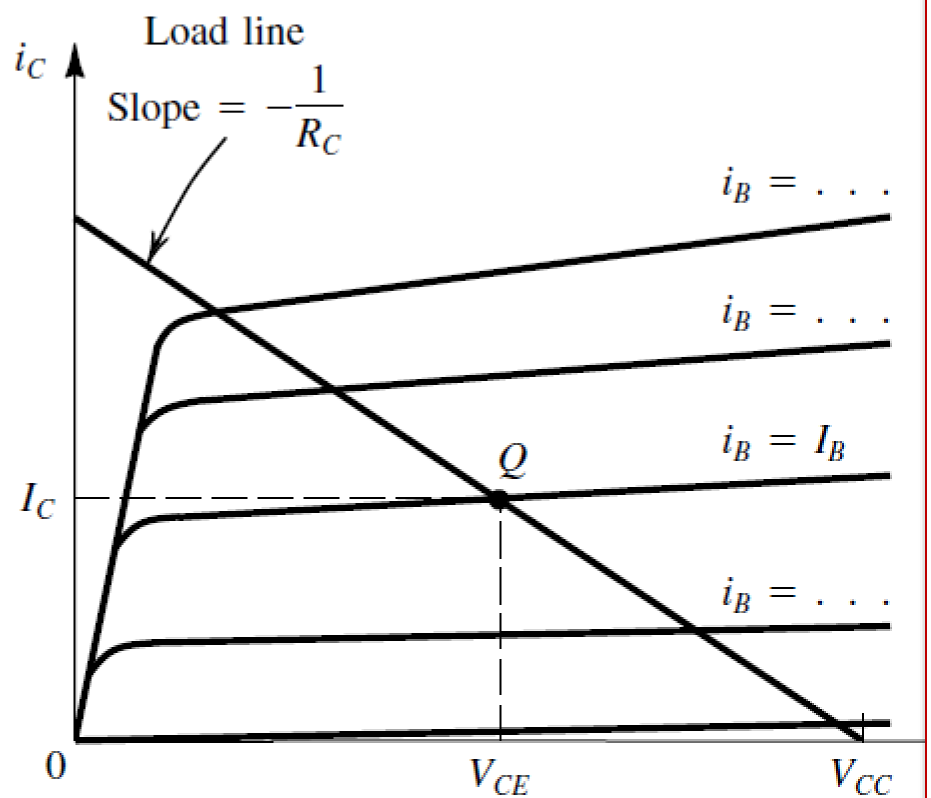
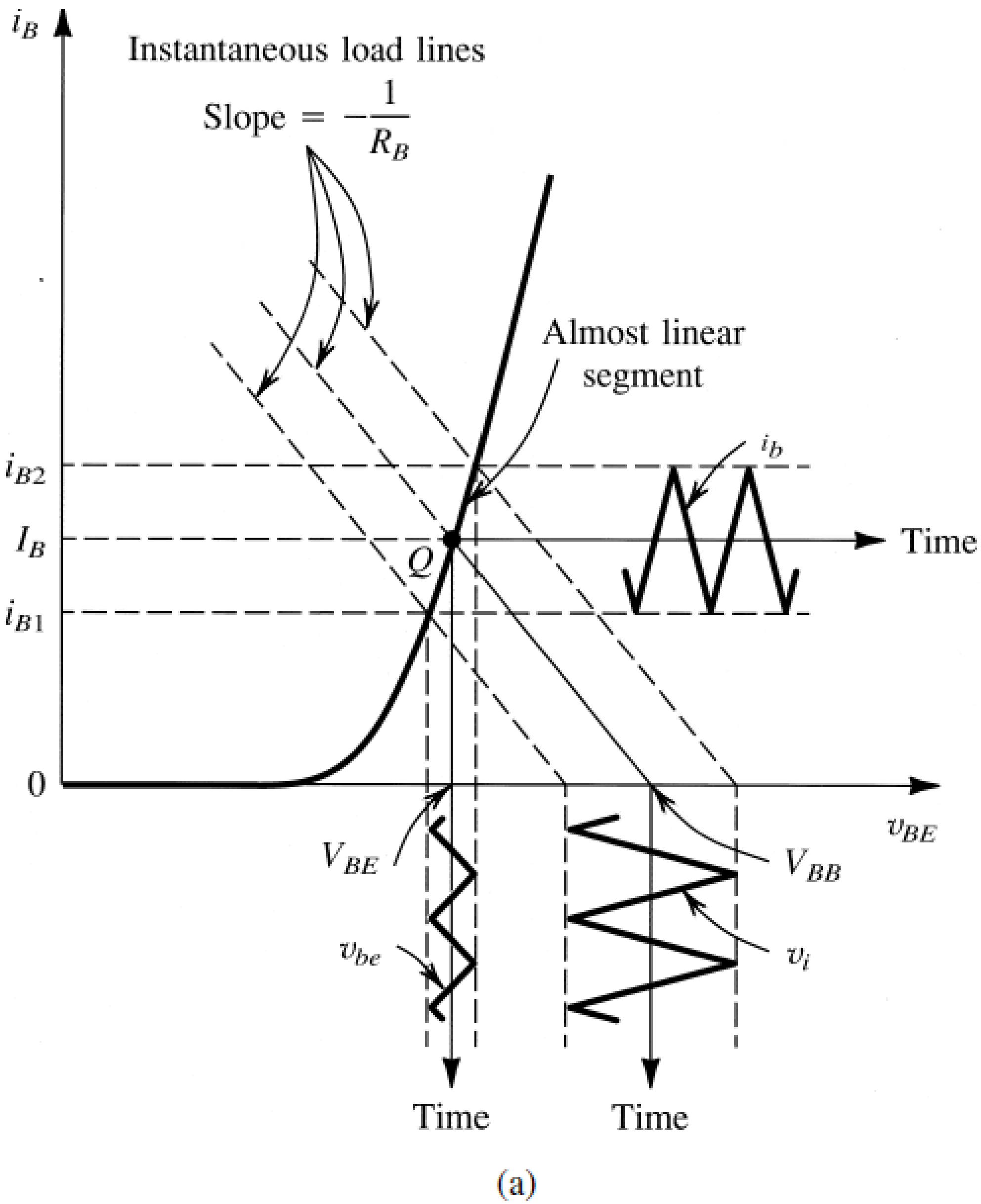


FIGURE 3.29 Graphical construction for determining the emitter voltage V_{CE} in the circuit of Fig. 3.27.

Note the iC vs. vCE characteristics is like a cc source with a shunt finite resistance Ro. Add to it st line of equation:

VCC – vCE– iC * Rc = 0.

This equation has a slope of -1/Rc. The point where it cuts the curve for a given iB value is Q-Point which gives us iC and vCE values.



Let us now add signal vi to VBB. It will cause minute changes to vBE and will cause minute changes in iB.

The relationship between vBE and iB will be linear as long as the swing is much smaller around Q –point.

contd

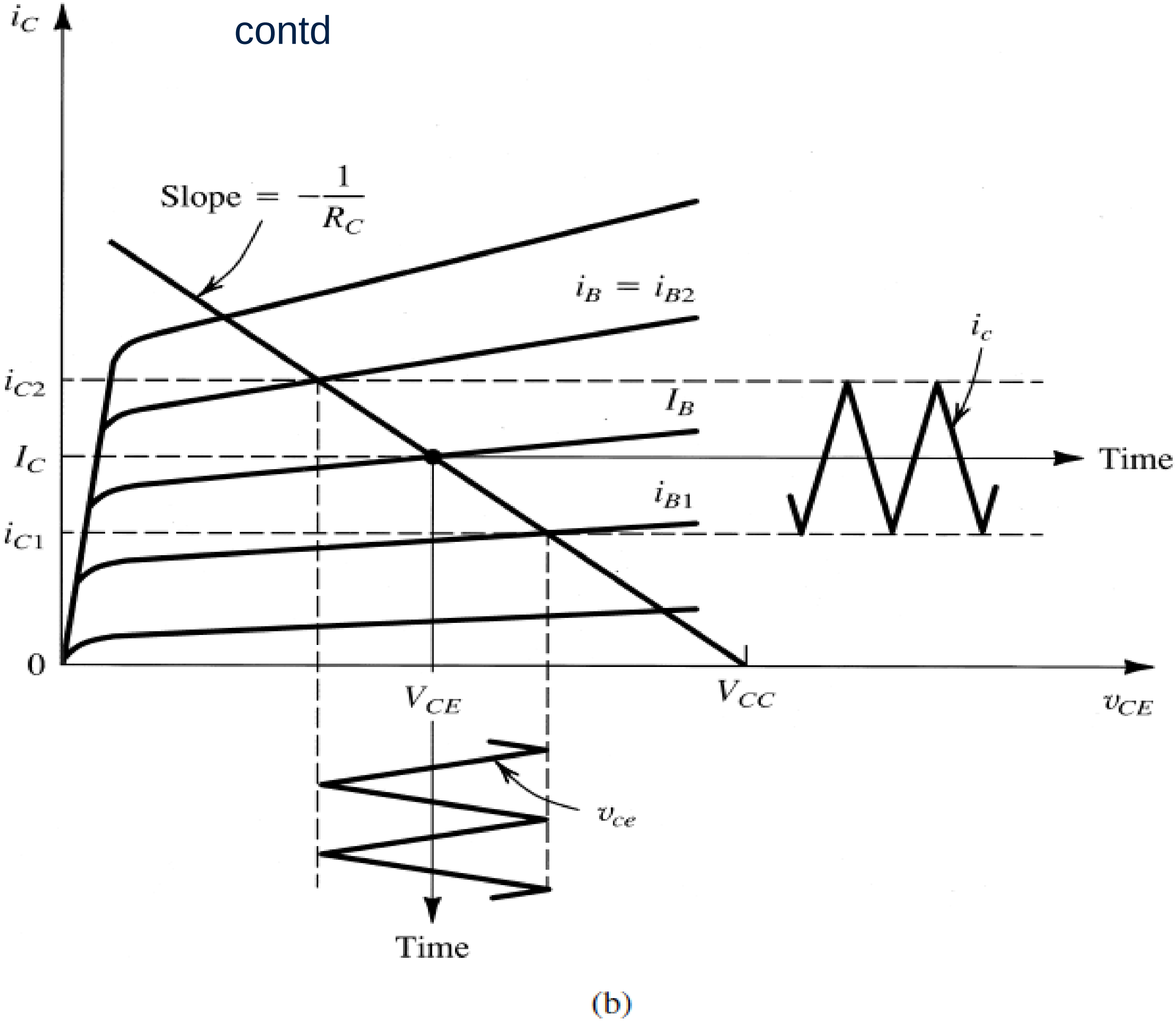


FIGURE 3.30 Graphical determination of the signal components v_{be}, i_b, i_c, an
component v_i is superimposed on the dc voltage V_{BE} (see Fig. 3.27).

Note that changes in iB around Q –Point, causes changes in iC and vCE, almost linearly.

Selection of Q Point

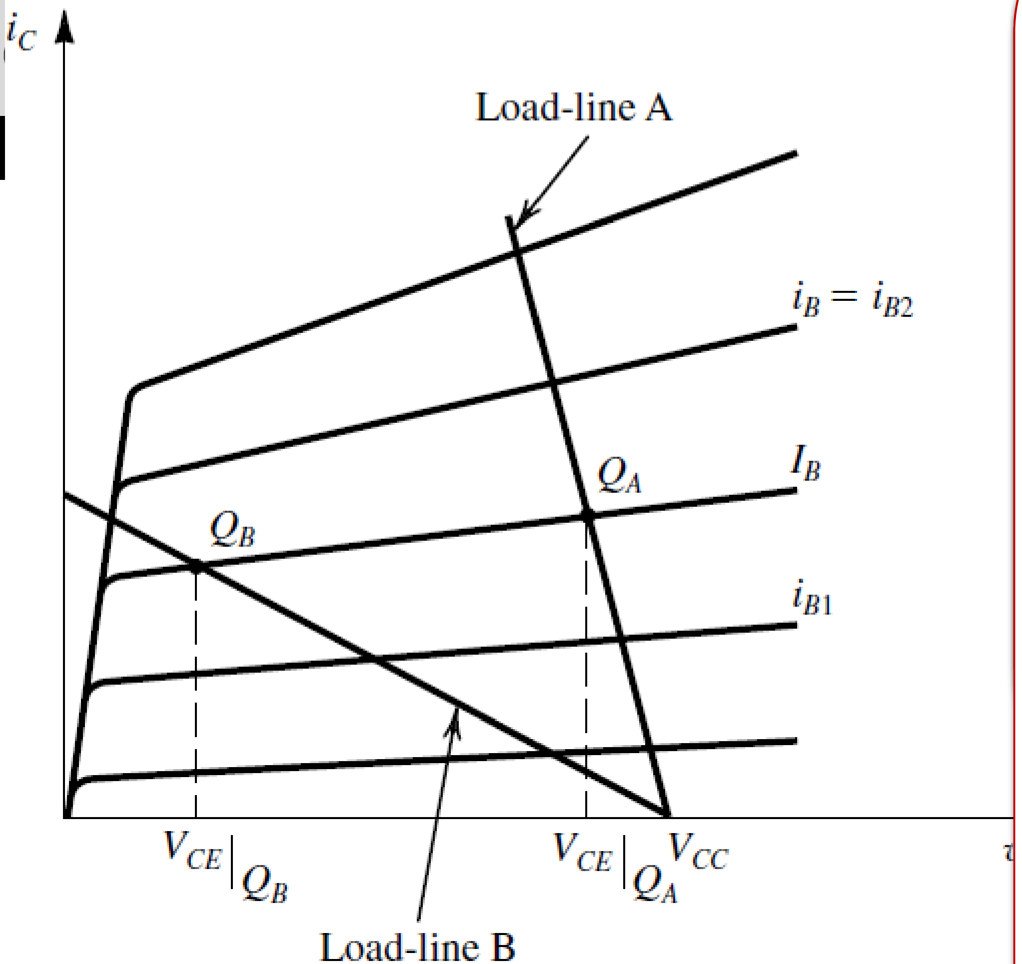


FIGURE 3.31 Effect of bias-point location on allowable
with a corresponding V_{CE} which is too close to V_{CC} and th
extreme, load-line B results in an operating point too close
swing of v_{CE}.

Let us now add signal vi to VBB. It will cause minute changes to vBE and will cause minute changes in iB.

The relationship between vBE and iB will be linear as long as the swing is much smaller around Q –point.

5.3.4 Operation as a Switch

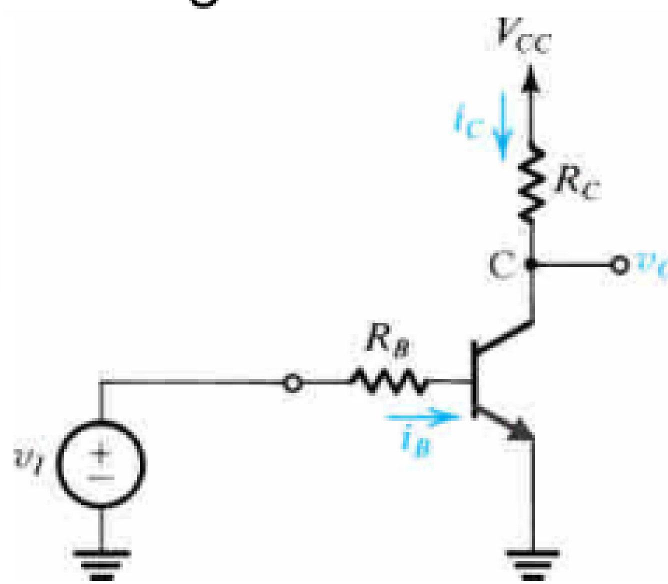
- To operate the BJT as a switch, we utilize the cutoff and the saturation modes of operation.

- For v_I less than about 0.5 V, the transistor will be cutoff; thus $i_B = 0, i_C = 0$, and $v_C = V_{CC}$

- To turn the transistor on, we have to increase v_I above 0.5 V. In fact, for appreciable currents to flow, *vBE* should be about 0.7 V and v_I should be higher.

$$i_B = \frac{v_I - V_{BE}}{R_B}$$

$$i_C = \beta i_B$$



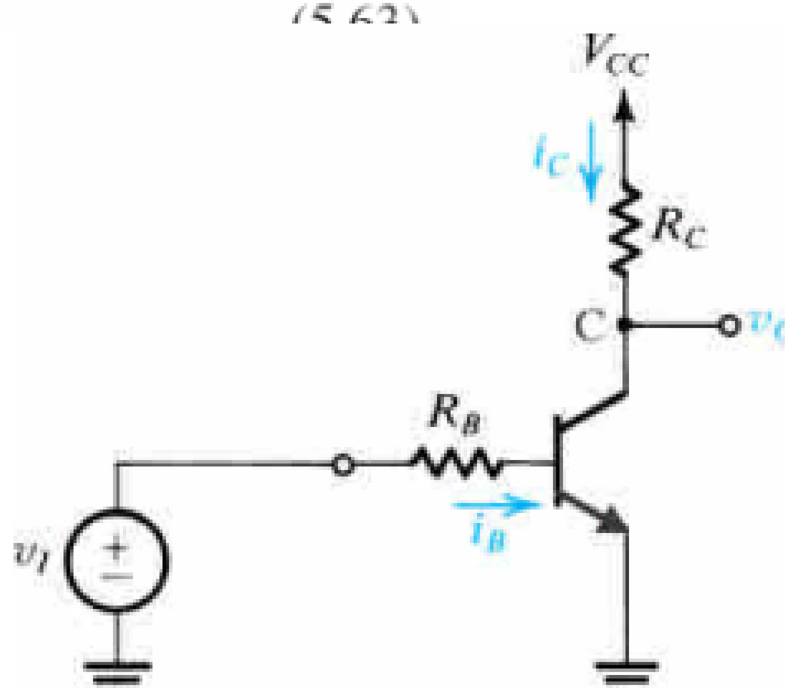
which applies only when the device is in the active mode. This will be the case as long as the CBJ is not forward biased, that is, as long as $vC > vB - 0.4$ V,

- Eventually, v_C will become lower than v_B by 0.4 V, at which point the transistor leaves the active region and enters the saturation region. This **edge-of-saturation (EOS)** point is defined by

$$I_{C(\text{EOS})} = \frac{V_{CC} - 0.3}{R_C} \qquad (5.63)$$

$$I_{B(\text{EOS})} = \frac{I_{C(\text{EOS})}}{\beta}$$

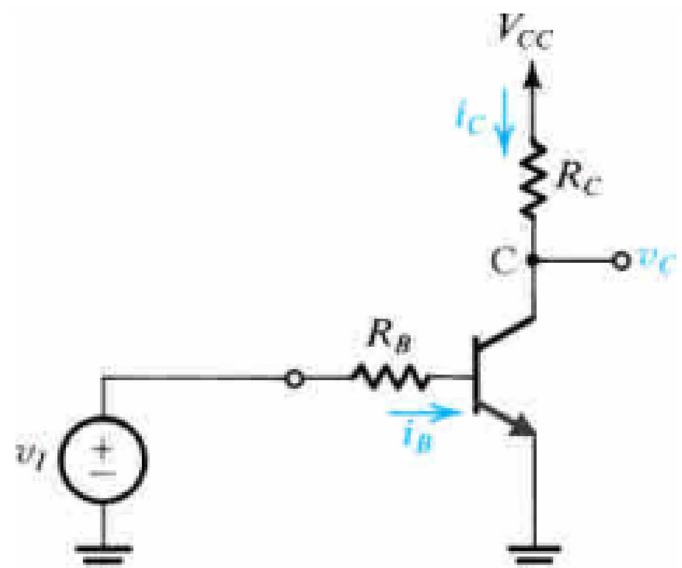
$$V_{I(\text{EOS})} = I_{B(\text{EOS})} R_B + V_{BE}$$



- we shall usually assume that for a saturated transistor, $V_{CEsat} \cong 0.2$ V.

$$I_{C\text{sat}} = \frac{V_{CC} - V_{CE\text{sat}}}{R_C} \qquad (5.66)$$

$$\beta_{\text{forced}} \equiv \frac{I_{C\text{sat}}}{I_B} \qquad (5.67)$$



- Let us solve some problems related to transistor currents and voltages. Use simpler and complex both models to see the error. Learn how to use given values to calculate unknown values.

Given beta = 100, vBE = 0.7v at 1 mA. Calculate Rc and Re such that Ic = 2 mA and Vc (Voltage at collector wrt GND) = 5V

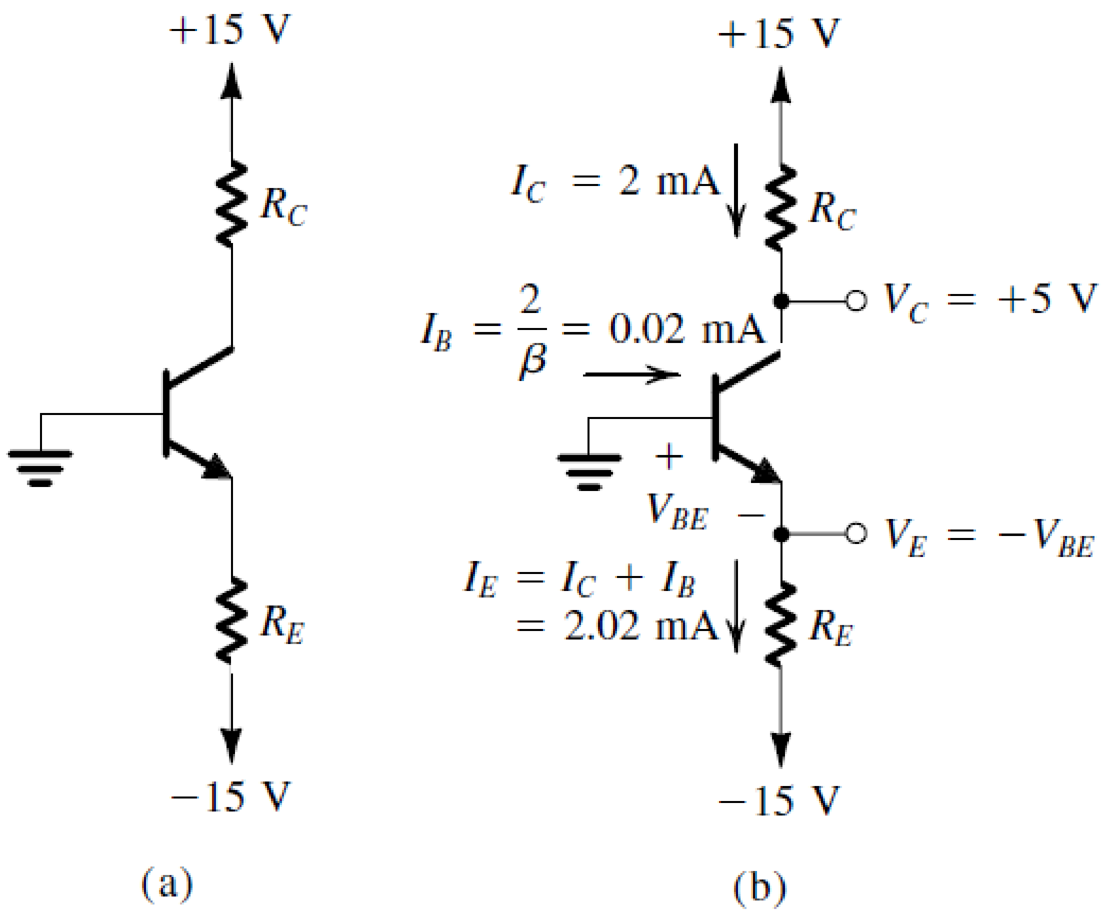


FIGURE 3.15 Circuit for Example 3.1.

Solution using crude model

1. Assume that vBE is 0.7V at all currents --1 mA or 2 mA.
2. Since Base is at 0V, Collector at positive voltage and emitter at negative voltage, we can assume that transistor will be in active region.
3. If Vc = 5V and Ic = 2 mA then
4. Using KVL, $V_c = 15V – i_C R_c$

   or $5V = 15V – 2\text{ mA} \times R_c$. We get $R_c = 5K$ ohms.

5. Vb = 0V or ground and since BJT is forward biased,

   $V_e = V_b - 0.7V = -0.7V$

6. Using KVL, $V_e = I_e R_e + (-15V)$

If we neglect iB then $i_E = i_C = 2$ mA and that gives us

$R_e = (15-0.7v)/ 2\text{ mA} = 7.15K$ We get $R_e = 7.15K$ ohms.

Solution using better model

1. Assume that vBE is 0.7V only at 1 mA. Now calculate vBE at 2 mA.

   vBE at 2 mA = vBE at 1 mA + VT ln (2/1) = 0.717V

2. Since Base is at 0V, Vc required = 5V and Ic = 2 mA then

Using KVL, Vc = 15V – IC Rc

or 5V = 15V – 2 mA x Rc . We get Rc = 5K ohms.

3. Vb = 0V or ground and since BJT is forward biased,

   Ve = Vb -0.717V = - 0.717V

4. Calculate iB = iC /beta = 2 mA /100 = 0.02 mA

5. Calculate iE = iB + iC = 2.02 mA

6. Using KVL, Ve = Ie Re + (-15V)

   Re = (15-0.717v)/ 2.02 mA = 7.07K. We get Re = 7.07K **The error is 0.08K in 7K or nearly 1% .**

Given vE = -0.7v and beta = 50, calculate all 3 currents and collector voltage.

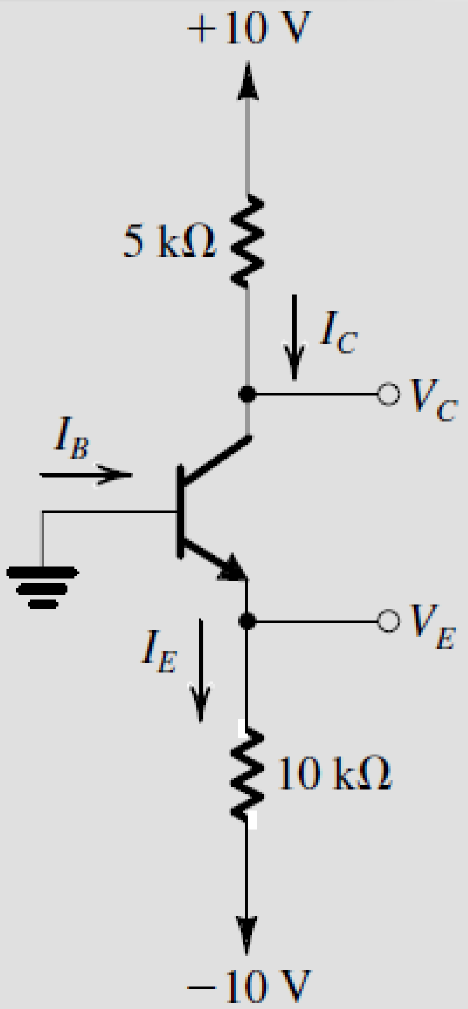


FIGURE E3.10

1. Calculate iE from vE and Re and -10V.
2. Calculate iB and iC.
3. Calculate vC from +10V and drop iC Rc .

Given vE = -0.7v and beta = 50, calculateall 3 currents and collector voltage.

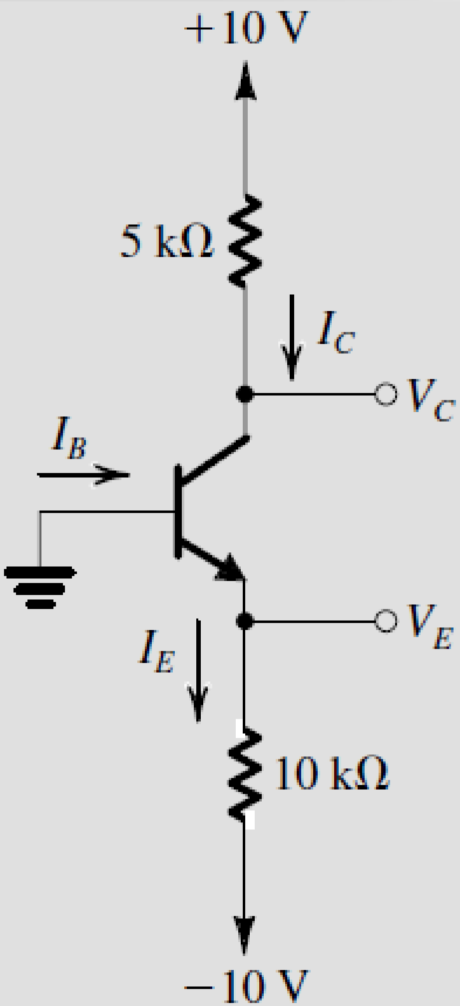


FIGURE E3.10

1. iE = (-.7 –(-10))/ 10K = 9.3V /10K = 0.93 mA
2. Alpha = beta / (beta+1)= 50/51 = 0.980392
3. iC = 0.980392 * 0.93 mA = 0.911 mA
4. iB = iC /beta = 0.911/50 = 0.18235 mA
5. Vc = 10V – iC Rc
   = 10V – 0.911 *5 = 5.44116 V

Given vB = 1.0v, vE = 1.7V. Calculate alpha, beta and Vc.

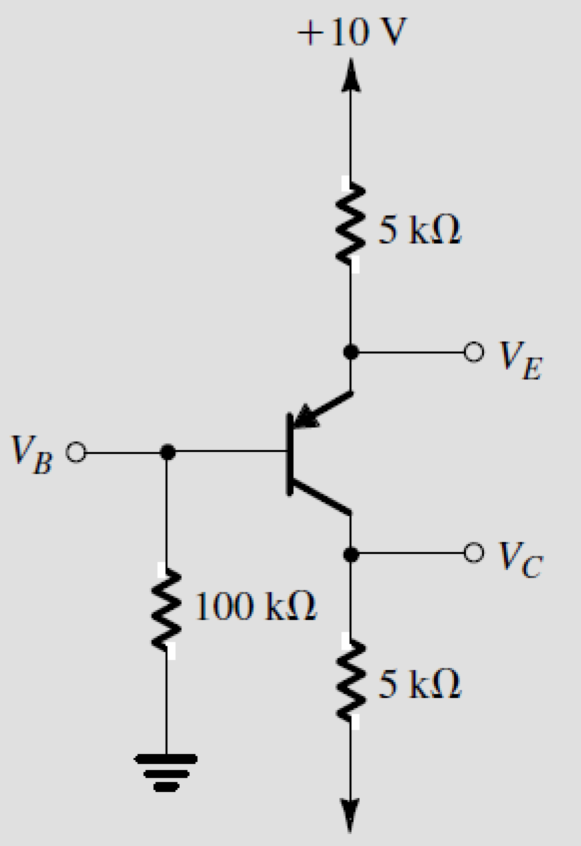


FIGURE E3.11

1. Calculate iE from drop across Re.
2. Calculate iB from drop across 100K.
3. Knowing these 2, get iC and Vc.
4. Calculate alpha, beta.

Given vB = 1.0v, vE = 1.7V. Calculate alpha, beta and Vc.

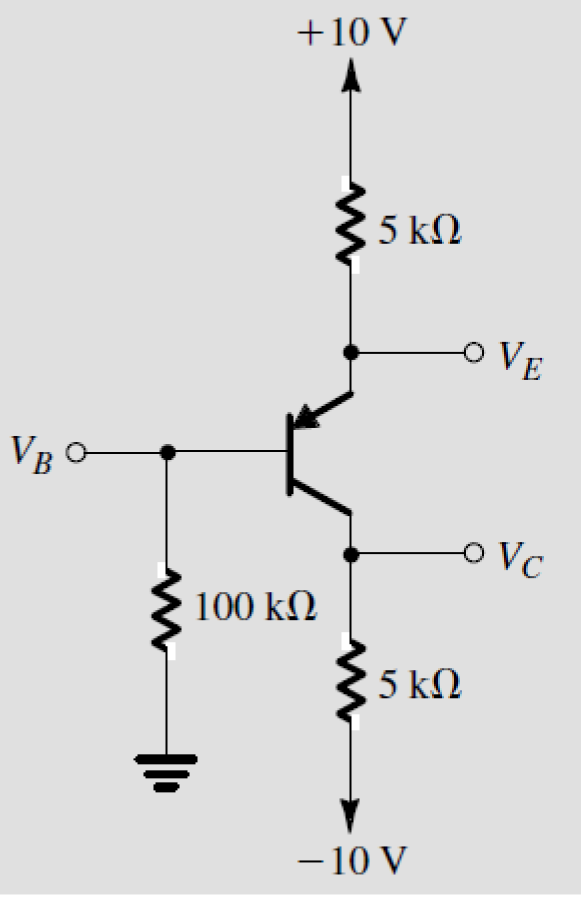
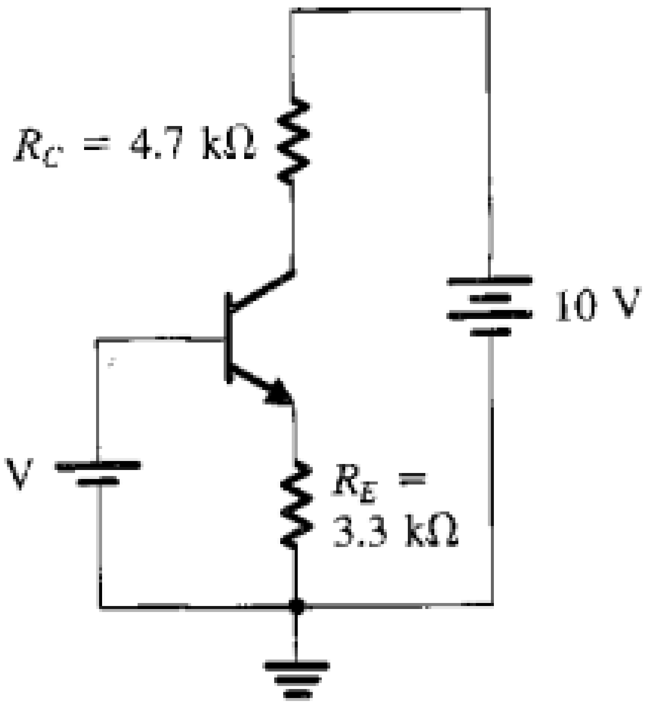


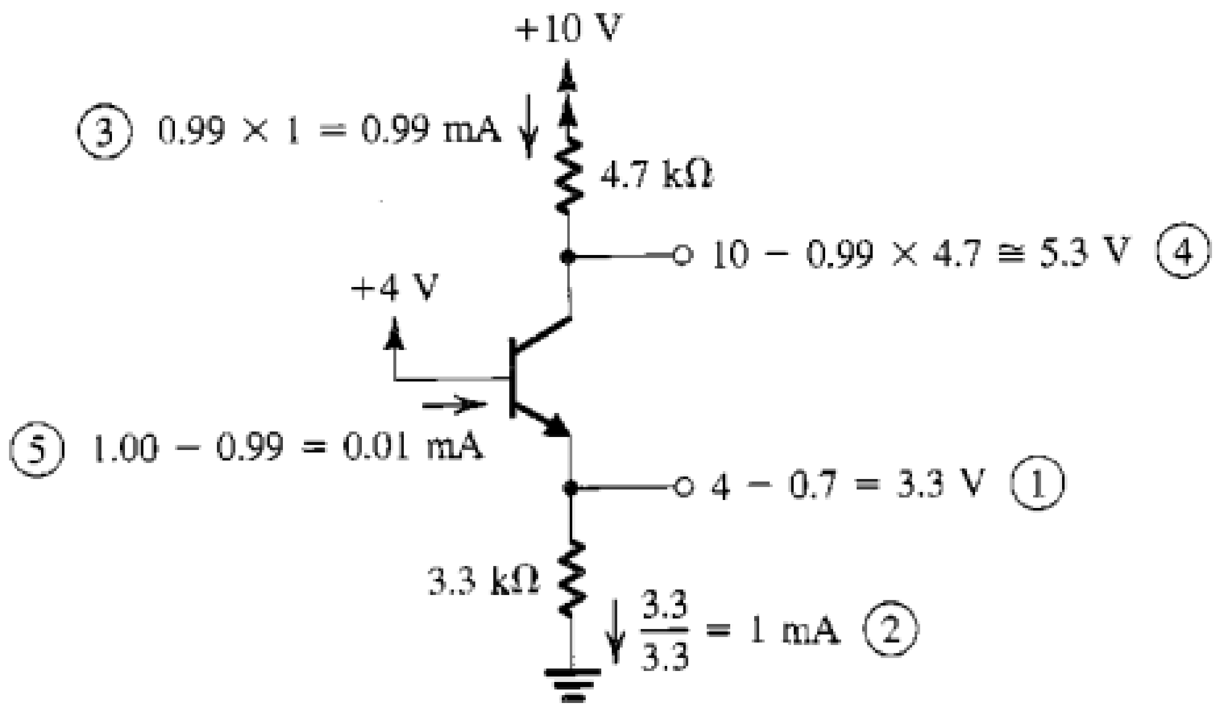
FIGURE E3.11

iE = (10-1.7)/5K = 1.66 mA
iB = 1V /100K = 0.01 mA
iC = iE – iB = 1.66-0.01
= 1.65 mA
vC = iC Rc + (-10V)
vC = 1.65 mA * 5K – 10V
= -1.75V
Alpha = iC /iE = 0.993976
Beta = iC /iB = 1.65 mA/ 0.01
= 165

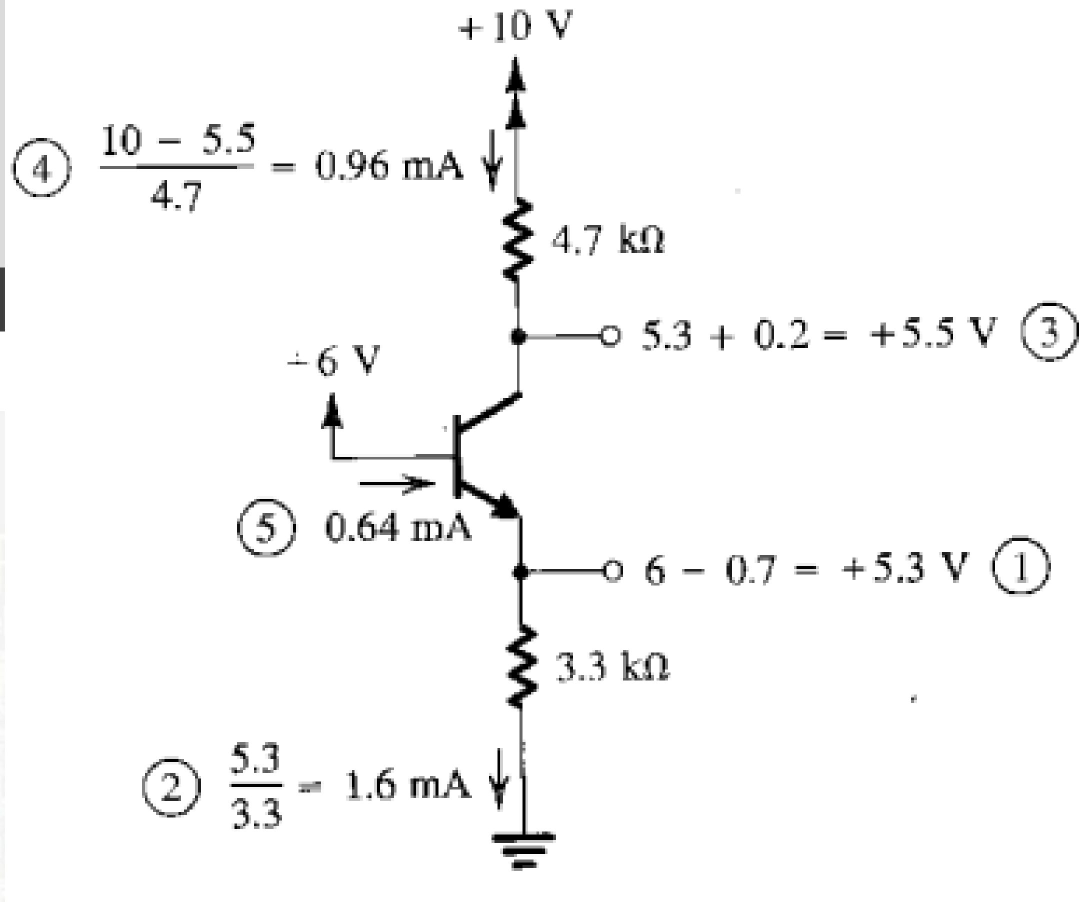
Analyze this circuit to determine all node voltages and branch currents. We will assume Beta as 100.



(b)



(c)



(c)

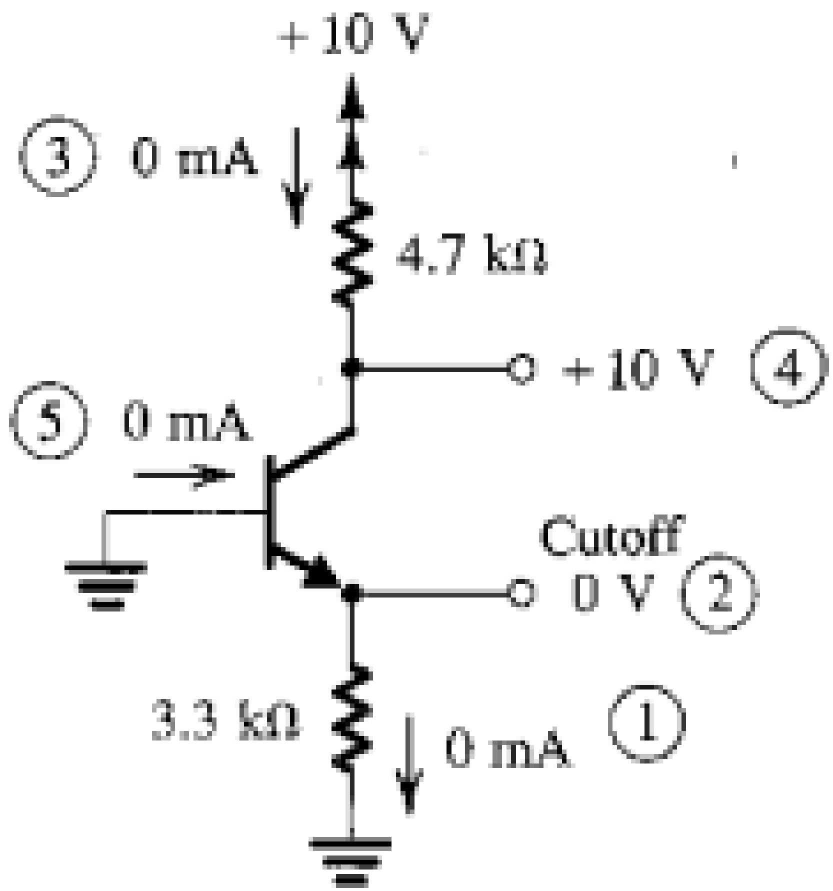
$$V_E = +6 - 0.7 = +5.3\text{ V}$$

$$I_E = \frac{V_E}{3.3} = \frac{5.3}{3.3} = 1.6\text{ mA}$$

$$V_C = V_E + V_{CEsat} \simeq +5.3 + 0.2 = +5.5\text{ V}$$

$$I_C = \frac{+10 - 5.5}{4.7} = 0.96\text{ mA}$$

$$I_B = I_E - I_C = 1.6 - 0.96 = 0.64\text{ mA}$$



(b)