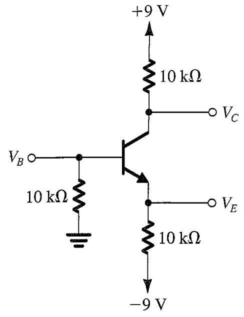

FIGURE P5.26

5.27 The current I_{CBO} of a small transistor is measured to be 20 nA at 25°C. If the temperature of the device is raised to 85°C, what do you expect I_{CBO} to become?

***5.28** Augment the model of the *npn* BJT shown in Fig. 5.20(a) by a current source representing I_{CBO}. Assume that r_o is very large and thus can be neglected. In terms of this addition, what do the terminal currents i_B, i_C, and i_E become? If the base lead is open-circuited while the emitter is connected to ground and the collector is connected to a positive supply, find the emitter and collector currents.

5.29 An *npn* transistor is accidentally connected with collector and emitter leads interchanged. The resulting currents in the normal emitter and base leads are 0.5 mA and 1 mA, respectively. What are the values of α_R and β_R?

5.30 A BJT whose emitter current is fixed at 1 mA has a base–emitter voltage of 0.69 V at 25°C. What base–emitter voltage would you expect at 0°C? At 100°C?

5.31 A particular *pnp* transistor operating at an emitter current of 0.5 mA at 20°C has an emitter–base voltage of 692 mV.

(a) What does v_{EB} become if the junction temperature rises to 50°C?
(b) If the transistor has $n = 1$ and is operated at a fixed emitter–base voltage of 700 mV, what emitter current flows at 20°C? At 50°C?

5.32 Consider a transistor for which the base–emitter voltage drop is 0.7 V at 10 mA. What current flows for $V_{BE} = 0.5$ V?

5.33 In Problem 5.32, the stated voltages are measured at 25°C. What values correspond at −25°C? At 125°C?

5.34 Use the Ebers-Moll expressions in Eqs. (5.26) and (5.27) to derive Eq. (5.35). Note that the emitter current is set to a constant value I_E. Ignore the terms not involving exponentials.

***5.35** Use Eq. (5.35) to plot the i_C–v_{CB} characteristics of an *npn* transistor having $\alpha_F \cong 1$, $\alpha_R = 0.1$, and $I_S = 10^{-15}$ A. Plot graphs for $I_E = 0.1$ mA, 0.5 mA, and 1 mA. Use an expanded scale for the negative values of v_{BC} in order to show the details of the saturation region. Neglect the Early effect.

***5.36** For the saturated transistor shown in Fig. P5.36, use the EM expressions to show that for $\alpha_F \cong 1$,

$$V_{CEsat} = V_T \ln \left(\frac{\dfrac{1}{\alpha_R} - \dfrac{I_{Csat}}{I_E}}{1 - \dfrac{I_{Csat}}{I_E}} \right)$$

For a BJT with $\alpha_R = 0.1$, evaluate V_{CEsat} for $I_{Csat}/I_E = 0.9$, 0.5, 0.1, and 0.

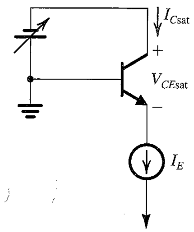

FIGURE P5.36

5.37 Use Eq. (5.36) to plot i_C versus v_{CE} for an *npn* transistor having $I_S = 10^{-15}$ A and $V_A = 100$ V. Provide curves for $v_{BE} = 0.65$, 0.70, 0.72, 0.73, and 0.74 volts. Show the characteristics for v_{CE} up to 15 V.

5.38 For a particular *npn* transistor operating at a v_{BE} of 670 mV and $I_C = 3$ mA, the i_C–v_{CE} characteristic has a slope of 3×10^{-5} ℧. To what value of output resistance does this correspond? What is the value of the Early voltage for this transistor? For operation at 30 mA, what would the output resistance become?

5.39 For a BJT having an Early voltage of 200 V, what is its output resistance at 1 mA? At 100 μA?

5.40 Measurements of the i_C–v_{CE} characteristic of a small-signal transistor operating at $v_{BE} = 720$ mV show that $i_C = 1.8$ mA at $v_{CE} = 2$ V and that $i_C = 2.4$ mA at $v_{CE} = 14$ V. What is the corresponding value of i_C near saturation? At what value of v_{CE} is $i_C = 2.0$ mA? What is the value of the Early voltage for this transistor? What is the output resistance that corresponds to operation at $v_{BE} = 720$ mV?

5.41 Give the *pnp* equivalent circuit models that correspond to those shown in Fig. 5.20 for the *npn* case.

5.42 A BJT operating at $i_B = 8$ μA and $i_C = 1.2$ mA undergoes a reduction in base current of 0.8 μA. It is found that when v_{CE} is held constant, the corresponding reduction in collector current is 0.1 mA. What are the values of h_{FE} and h_{fe} that apply? If the base current is increased from 8 μA to 10 μA and v_{CE} is increased from 8 V to 10 V, what collector current results? Assume $V_A = 100$ V.

5.43 For a transistor whose β characteristic is sketched in Fig. 5.22, estimate values of β at −55°C, 25°C, and 125°C for $I_C = 100$ μA and 10 mA. For each current, estimate the temperature coefficient for temperatures above and below room temperature (four values needed).

5.44 Figure P5.44 shows a diode-connected *npn* transistor. Since $v_{CB} = 0$ results in active mode operation, the BJT will internally operate in the active mode; that is, its base and collector currents will be related by β_F. Use the EM equations to show that the diode-connected transistor has the i–v characteristics,

$$i = \frac{I_S}{\alpha_F}(e^{v/V_T} - 1) \cong I_S e^{v/V_T}$$

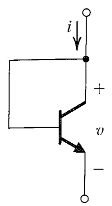

FIGURE P5.44

5.45 A BJT for which $\alpha_R = 0.2$ operates with a constant base current but with the collector open. What value of V_{CEsat} would you measure?

5.46 Find the saturation voltage V_{CEsat} and the saturation resistance R_{CEsat} of an *npn* BJT operated at a constant base current of 0.1 mA and a forced β of 20. The transistor has $\beta_F = 50$ and $\beta_R = 0.2$.

***5.47** Use Eq. (5.47) to show that the saturation resistance $R_{CEsat} \equiv \partial v_{CE}/\partial i_C$ of a transistor operated with a constant base current I_B is given by

$$R_{CEsat} = \frac{V_T}{\beta_F I_B} \frac{1}{x(1-x)}$$

where

$$x = \frac{I_{Csat}}{\beta_F I_B} = \frac{\beta_{forced}}{\beta_F}$$

Find R_{CEsat} for $\beta_{forced} = \beta_F/2$.

5.48 For a transistor for which $\beta_F = 70$ and $\beta_R = 0.7$, find an estimate of R_{CEsat} and V_{CEoff} for $I_B = 2$ mA by evaluating V_{CEsat} at $i_C = 3$ mA and at $i_C = 0.3$ mA (using Eq. 5.49). (*Note:* Because here we are modeling operation at a very low forced β, the value of R_{CEsat} will be much larger than that given by Eq. 5.48).

5.49 A transistor has $\beta_F = 150$ and the collector junction is 10 times larger than the emitter junction. Evaluate V_{CEsat} for $\beta_{forced}/\beta_F = 0.99$, 0.95, 0.9, 0.5, 0.1, 0.01, and 0.

5.50 A particular *npn* BJT with $v_{BE} = 720$ mV at $i_C = 600$ μA, and having $\beta = 150$, has a collector–base junction 20 times larger than the emitter–base junction.

(a) Find α_F, α_R, and β_R.
(b) For a collector current of 5 mA and nonsaturated operation, what is the base–emitter voltage and the base current?
(c) For the situation in (b) but with double the calculated base current, what is the value of forced β? What are the base–emitter and base–collector voltages? What are V_{CEsat} and R_{CEsat}?

***5.51** A BJT with fixed base current has $V_{CEsat} = 60$ mV with the emitter grounded and the collector open-circuited. When the collector is grounded and the emitter is open-circuited, V_{CEsat} becomes −1 mV. Estimate values for β_R and β_F for this transistor.

5.52 A BJT for which $I_B = 0.5$ mA has $V_{CEsat} = 140$ mV at $I_C = 10$ mA and $V_{CEsat} = 170$ mV at $I_C = 20$ mA. Estimate the values of its saturation resistance, R_{CEsat}, and its offset voltage, V_{CEoff}. Also, determine the values of β_F and β_R.

5.53 A BJT for which BV_{CBO} is 30 V is connected as shown in Fig. P5.53. What voltages would you measure on the collector, base, and emitter?

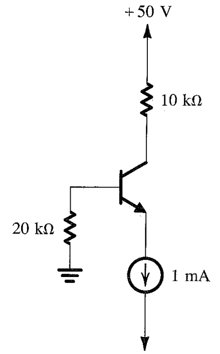

FIGURE P5.53

SECTION 5.3: THE BJT AS AN AMPLIFIER AND AS A SWITCH

5.54 A common-emitter amplifier circuit operated with $V_{CC} = +10$ V is biased at $V_{CE} = +1$ V. Find the voltage gain, the maximum allowed output negative swing without the transistor entering saturation, and the corresponding maximum input signal permitted.

5.55 For the common-emitter circuit in Fig. 5.26(a) with $V_{CC} = +10$ V and $R_C = 1$ kΩ, find V_{CE} and the voltage gain at the following dc collector bias currents: 1 mA, 2 mA, 5 mA, 8 mA, and 9 mA. For each, give the maximum possible positive- and