6.13 A BJT is specified to have $I_S = 5 \times 10^{-15}$ A and β that falls in the range of 50 to 200. If the transistor is operated in the active mode with v_{BE} set to 0.700 V, find the expected range of i_C, i_B, and i_E.

6.14 Measurements made on a number of transistors operating in the active mode with $i_E = 1$ mA indicate base currents of 10 μA, 20 μA, and 50 μA. For each device, find i_C, β, and α.

6.15 Measurements of V_{BE} and two terminal currents taken on a number of *npn* transistors operating in the active mode are tabulated below. For each, calculate the missing current value as well as α, β, and I_S as indicated by the table.

Transistor	a	b	c	d	e
V_{BE} (mV)	700	690	580	780	820
I_C (mA)	1.000	1.000		10.10	
I_B (μA)	10		5	120	1050
I_E (mA)		1.020	0.235		75.00
α					
β					
I_S					

6.16 When operated in the active mode, a particular *npn* BJT conducts a collector current of 1 mA and has $v_{BE} = 0.70$ V and $i_B = 10$ μA. Use these data to create specific transistor models of the form shown in Fig. 6.5(a) to (d).

6.17 Using the *npn* transistor model of Fig. 6.5(b), consider the case of a transistor for which the base is connected to ground, the collector is connected to a 5-V dc source through a 2-kΩ resistor, and a 2-mA current source is connected to the emitter with the polarity so that current is drawn out of the emitter terminal. If $\beta = 100$ and $I_S = 5 \times 10^{-15}$ A, find the voltages at the emitter and the collector and calculate the base current.

D 6.18 Consider an *npn* transistor operated in the active mode and represented by the model of Fig. 6.5(d). Let the transistor be connected as indicated by the equivalent circuit shown in Fig. 6.6(b). It is required to calculate the values of R_B and R_C that will establish a collector current I_C of 0.5 mA and a collector-to-emitter voltage V_{CE} of 1 V. The BJT is specified to have $\beta = 50$ and $I_S = 5 \times 10^{-15}$ A.

6.19 An *npn* transistor has a CBJ with an area 100 times that of the EBJ. If $I_S = 10^{-15}$ A, find the voltage drop across EBJ and across CBJ when each is forward biased and conducting a current of 1 mA. Also find the forward current each junction would conduct when forward biased with 0.5 V.

*6.20 We wish to investigate the operation of the *npn* transistor in saturation using the model of Fig. 6.9. Let $I_S = 10^{-15}$ A, $v_{BE} = 0.7$ V, $\beta = 100$, and $I_{SC}/I_S = 100$. For each of three values of v_{CE} (namely, 0.4 V, 0.3 V, and 0.2 V), find v_{BC}, i_{BC}, i_{BE}, i_B, i_C, and i_C/i_B. Present your results in tabular form. Also find v_{CE} that results in $i_C = 0$.

*6.21 Use Eqs. (6.14), (6.15), and (6.16) to show that an *npn* transistor operated in saturation exhibits a collector-to-emitter voltage, V_{CEsat}, given by

$$V_{CEsat} = V_T \ln\left[\left(\frac{I_{SC}}{I_S}\right)\frac{1+\beta_{forced}}{1-\beta_{forced}/\beta}\right]$$

Use this relationship to evaluate V_{CEsat} for $\beta_{forced} = 50$, 10, 5, and 1 for a transistor with $\beta = 100$ and with a CBJ area 100 times that of the EBJ. Present your results in a table.

6.22 Consider the *pnp* large-signal model of Fig. 6.11(b) applied to a transistor having $I_S = 10^{-14}$ A and $\beta = 50$. If the emitter is connected to ground, the base is connected to a current source that pulls 10 μA out of the base terminal, and the collector is connected to a negative supply of −5 V via a 8.2-kΩ resistor, find the collector voltage, the emitter current, and the base voltage.

6.23 A *pnp* transistor has $v_{EB} = 0.7$ V at a collector current of 1 mA. What do you expect v_{EB} to become at $i_C = 10$ mA? At $i_C = 100$ mA?

6.24 A *pnp* transistor modeled with the circuit in Fig. 6.11 (b) is connected with its base at ground, collector at −2.0 V, and a 1-mA current is injected into its emitter. If the transistor is said to have $\beta = 10$, what are its base and collector currents? In which direction do they flow? If $I_S = 10^{-15}$ A, what voltage results at the emitter? What does the collector current become if a transistor with $\beta = 1000$ is substituted? (*Note:* The fact that the collector current changes by less than 10% for a large change in β illustrates that this is a good way to establish a specific collector current.)

6.25 A *pnp* power transistor operates with an emitter-to-collector voltage of 5 V, an emitter current of 5 A, and $V_{EB} = 0.8$ V. For $\beta = 20$, what base current is required? What is I_S for this transistor? Compare the emitter–base junction area of this transistor with that of a small-signal

SIM = Multisim/PSpice; * = difficult problem; ** = more difficult; *** = very challenging; D = design problem transistor that conducts $i_C = 1$ mA with $v_{EB} = 0.70$ V. How much larger is it?

6.26 While Fig. 6.5 provides four possible large-signal equivalent circuits for the *npn* transistor, only two equivalent circuits for the *pnp* transistor are provided in Fig. 6.11. Supply the missing two.

6.27 By analogy to the *npn* case shown in Fig. 6.9, give the equivalent circuit of a *pnp* transistor in saturation.

Section 6.2: Current–Voltage Characteristics

6.28 For the circuits in Fig. P6.28, assume that the transistors have very large β. Some measurements have been made on these circuits, with the results indicated in the figure. Find the values of the other labeled voltages and currents.

6.29 Measurements on the circuits of Fig. P6.29 produce labeled voltages as indicated. Find the value of β for each transistor.

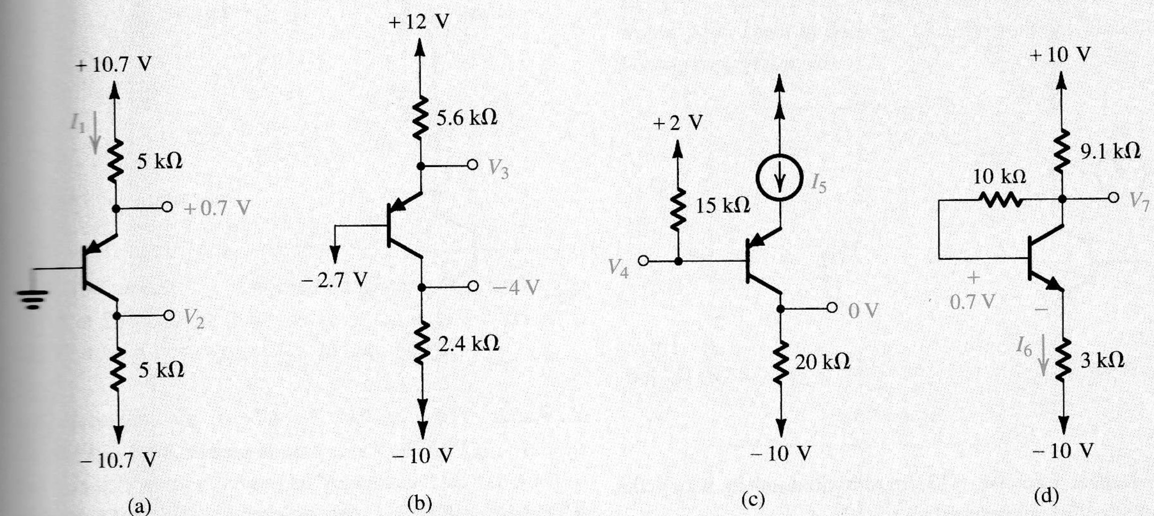

Figure P6.28

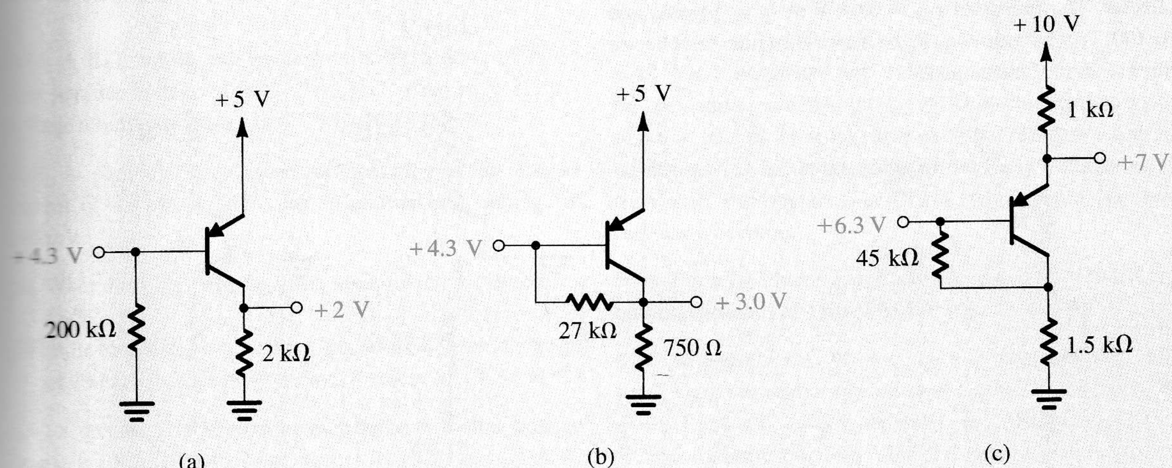

Figure P6.29

*6.66 For the circuit shown in Fig. P6.66, find the labeled node voltages for:

(a) $\beta = \infty$
(b) $\beta = 100$

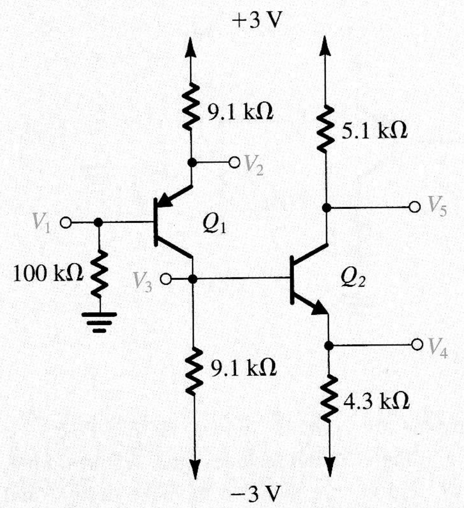

Figure P6.66

D *6.67 Using $\beta = \infty$, design the circuit shown in Fig. P6.67 so that the emitter currents of Q_1, Q_2, and Q_3 are 0.5 mA, 0.5 mA, and 1 mA, respectively, and $V_3 = 0$, $V_5 = -2$ V, and $V_7 = 1$ V. For each resistor, select the nearest standard value utilizing the table of standard values for 5% resistors in Appendix J. Now, for $\beta = 100$, find the values of V_3, V_4, V_5, V_6, and V_7.

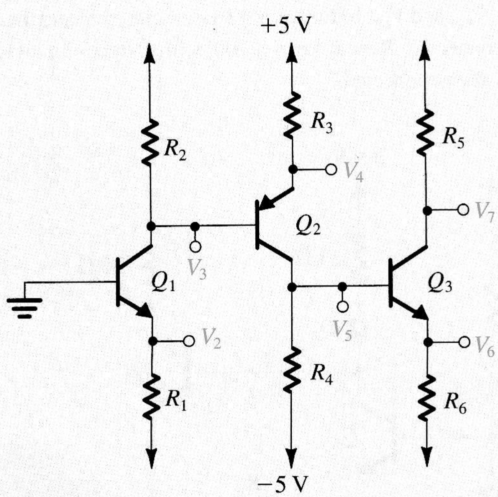

Figure P6.67

*6.68 For the circuit in Fig. P6.68, find V_B and V_E for v_I = 0 V, +2 V, −2.5 V, and −5 V. The BJTs have $\beta = 50$.

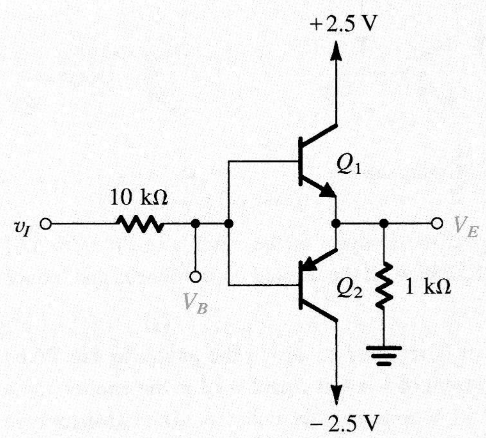

Figure P6.68

**6.69 All the transistors in the circuits of Fig. P6.69 are specified to have a minimum β of 50. Find approximate values for the collector voltages and calculate forced β for each of the transistors. (*Hint:* Initially, assume all transistors are operating in saturation, and verify the assumption.)