Homework #11

Problems 6.7, 6.8, 6.28, 6.29, and 6.32

Problem 6.7

Consider an *npn* transistor whose base-emitter drop is 0.76 V at a collector current of 5 mA. What current will it conduct at v_{BE} = 0.70 V? What is its base-emitter voltage for I_C = 5 μA?

$$V_{BE} = 0.76\text{ V} \qquad V_T = 0.025\text{ V} \qquad I_C = 5\text{ mA} = I_S e^{V_{BE}/V_T}$$

$$I_S = \frac{5\text{ mA}}{e^{V_{BE}/V_T}} = 3.137 \times 10^{-16}\text{A}$$

$$V_{BE} = 0.7\text{ V}$$

$$I_C = I_S e^{V_{BE}/V_T} = 3.137 \times 10^{-16} e^{700/25} = 453.59\ \mu\text{A}$$

$$I_C = 5\ \mu\text{A}$$

$$V_{BE} = V_T \ln\left(\frac{I_C}{I_S}\right) = .025\ln\left(\frac{10 \times 10^{-6}}{3.137 \times 10^{-16}}\right) = 0.587\text{V}$$

Problem 6.8

In a particular BJT, the base current is 10 μA, and the collector current is 800 μA. Find β and α for this device.

$$\beta \equiv \frac{i_C}{i_B}$$

β is the common-emitter current gain

$$\alpha \equiv \frac{i_C}{i_E}$$

α is the common-base current gain

$$i_B = \frac{i_C}{\beta}$$

$$\beta = \frac{i_C}{i_B} = \frac{800\ \mu A}{10\ \mu A} = 80$$

$$\alpha = \frac{\beta}{\beta + 1} = \frac{80}{80 + 1} = 0.9877$$

$$\alpha \equiv \frac{i_C}{i_E} = \frac{i_C}{i_C + i_B} = \frac{800\mu A}{810\mu A} = 0.9877$$

Problem 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.

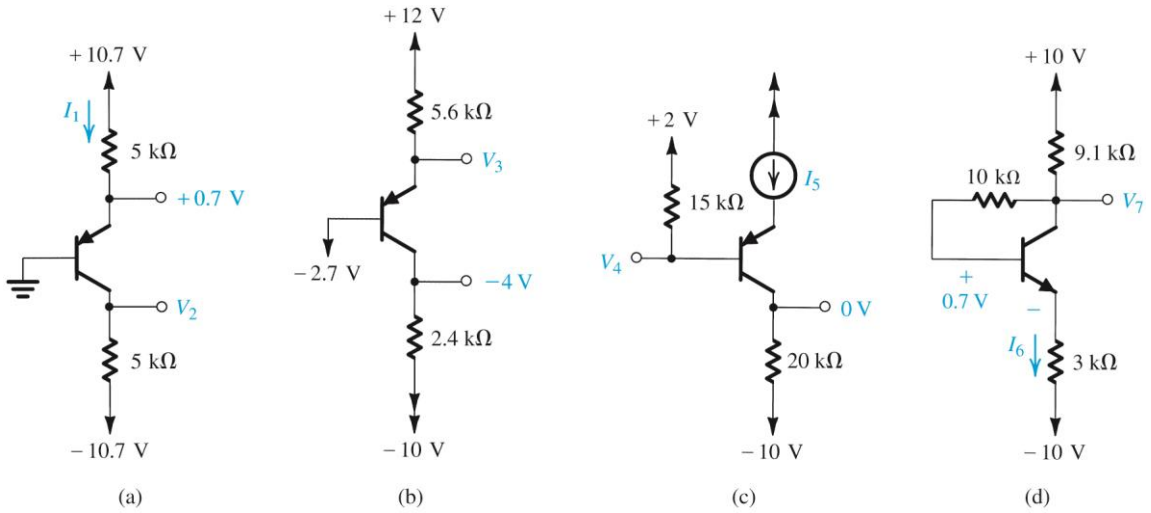


Figure P6.28

Problem 6.28a

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.

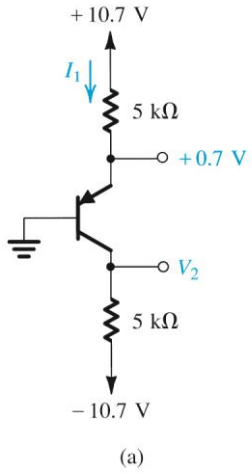


Figure P6.28

$$\beta \equiv \frac{i_C}{i_B} \Rightarrow i_B = \frac{i_C}{\beta}$$

Very large β means $I_E = I_C$ ($I_B \approx 0$)

$$I_1 = I_E = \frac{10.7\ \text{V} - 0.7\ \text{V}}{10\ \text{k}\Omega} = 2\ \text{mA}$$

$$V_2 = V_C = -10.7\ \text{V} + 5\ \text{k}\Omega \times 2\ \text{mA} = -0.7\ \text{V}$$

Problem 6.28b

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.

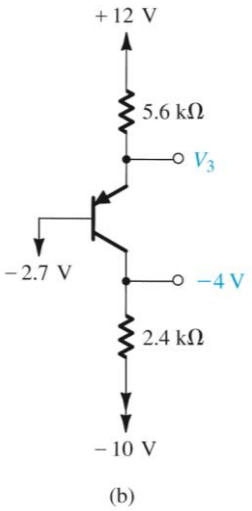


Figure P6.28

Very large β means $I_E = I_C$ ($I_B \approx 0$)

$$I_E = I_C = \frac{-4\text{ V} - -10\text{ V}}{2.4\text{ k}\Omega} = 2.5\text{ mA}$$

$$V_3 = V_E = 12\text{ V} - 5.6\text{ k}\Omega \times 2.5\text{ mA} = -2\text{ V}$$

Problem 6.28c

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.

Very large β means $I_E = I_C$ ($I_B \approx 0$)

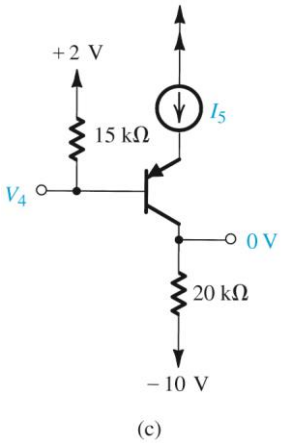


Figure P6.28

$$I_5 = I_E = \frac{10\text{ V}}{20\text{ k}\Omega} = 0.5\text{ mA}$$

$$V_4 = V_B = 2\text{ V}$$

Problem 6.28d

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.

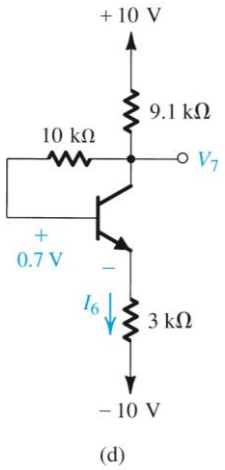


Figure P6.28

Very large β means $I_E = I_C$ ($I_B \approx 0$)

$$I_6 = I_E = I_C = \frac{V_B - 0.7\text{V} + 10\text{ V}}{3\text{ k}\Omega} = \frac{10\text{ V} - V_C}{9.1\text{ k}\Omega}$$

$$9.1\text{ k}\Omega(V_B + 9.3\text{ V}) = 3\text{ k}\Omega(10\text{ V} - V_C)$$

$$9.1V_B + 84.63 = 30 - 3V_C \qquad V_7 = V_C = V_B$$

$$12.1V_7 = -54.63$$

$$V_7 = -4.515\text{V}$$

$$I_6 = I_E = I_C = \frac{10\text{ V} + 4.515}{9.1\text{ k}\Omega} = 1.595\text{ mA}$$

Problem 6.29a,b

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

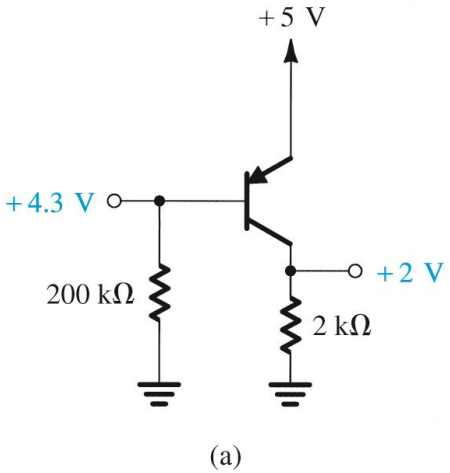
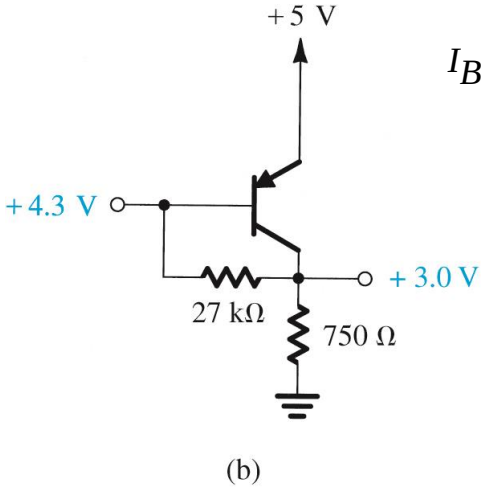


Figure P6.29

$$I_C := \frac{2V}{2k\Omega} = 1\,mA$$

$$I_B := \frac{4.3\,V}{200\,k\Omega} = 21.5\ \mu A$$

$$\beta := \frac{I_C}{I_B} = 46.512$$



$$I_B := \frac{4.3\,V - 3.0\,V}{27\,k\Omega} = 48.148\ \mu A$$

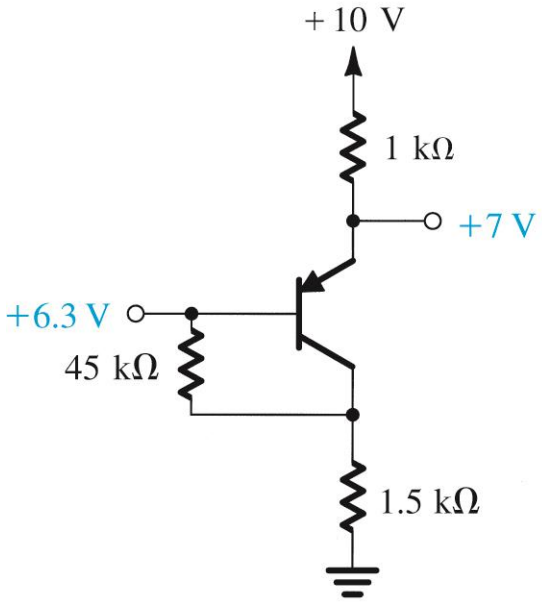
$$I_R := \frac{3V}{750\,\Omega} = 4\,mA$$

$$I_C := I_R - I_B = 3.952\ mA$$

$$\beta := \frac{I_C}{I_B} = 82.077$$

Problem 6.29c

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



(c)

Figure P6.29

$$I_E = \frac{10\text{ V} - 7\text{ V}}{1\text{ k}\Omega} = 3\text{ mA}$$

$$I_E = I_C + I_B$$

$$V_C = (I_C + I_B)1.5\text{k}\Omega = 3\text{ mA} \times 1.5\text{ k}\Omega = 4.5\text{ V}$$

$$I_B = \frac{6.3\text{ V} - 4.5\text{ V}}{45\text{ k}\Omega} = 40\ \mu\text{A}$$

$$I_C = 3\text{ mA} - 40\ \mu\text{A} = 2.96\text{ mA}$$

$$\beta = \frac{i_C}{i_B} = \frac{2.96\text{ mA}}{40\ \mu\text{A}} = 74$$

Problem 6.32a

Design the circuit in Fig. P6.32 to establish a current of 0.5 mA in the emitter and a voltage of -0.5 V at the collector. The transistor v_{EB} = 0.64 V at I_E = 0.1 mA, and β = 100. To what value can R_C be increased while the collector current remains unchanged?

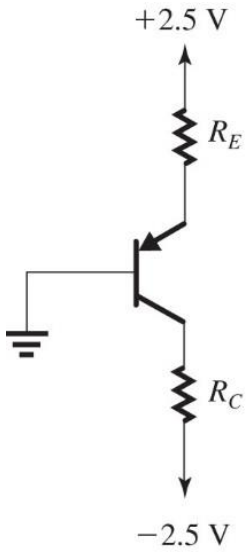


Figure P6.32

$$\beta := 100 \qquad \alpha := \frac{\beta}{\beta + 1} = 0.9901 \qquad V_{EB} := 0.64\,V \qquad I_E := 0.1\,mA$$

Method 1

$$I_C := \alpha\, I_E = 0.099\ mA \qquad I_S := I_C \cdot e^{\frac{-V_{EB}}{V_T}} = 0.755\ fA$$

$$I_E := 0.5\,mA \qquad I_C := \alpha\, I_E = 0.495\ mA \qquad V_{EB} := V_T \cdot ln\left(\frac{I_C}{I_S}\right) = 0.68\ V$$

Method 2

$$\frac{I_{E2}}{I_{E1}} = \frac{\alpha I_S e^{V_{EB2}/V_T}}{\alpha I_S e^{V_{EB1}/V_T}} = e^{(V_{EB2} - V_{EB1})/V_T} \qquad \Rightarrow V_{EB2} = V_T \ln\left(\frac{I_{E2}}{I_{E1}}\right) + V_{EB1}$$

$$V_{EB} := 25mV \cdot ln\left(\frac{0.5\,mA}{0.1\,mA}\right) + 0.64\,V = 0.68\ V$$

Problem 6.32b

Design the circuit in Fig. P6.32 to establish a current of 0.5 mA in the emitter and a voltage of -0.5 V at the collector. The transistor v_{EB} = 0.64 V at I_E = 0.1 mA, and β = 100. To what value can R_C be increased while the collector current remains unchanged?

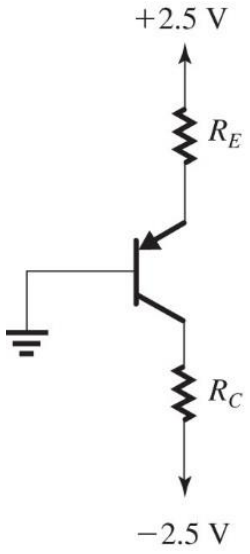


Figure P6.32

$$V_{EB} = 0.68\ \text{V}$$

$$R_E = \frac{2.5\ \text{V} - 0.68\ \text{V}}{0.5\ \text{mA}} = 3.64\ \text{k}\Omega$$

$$R_C = \frac{-0.5\text{V} - -2.5\ \text{V}}{0.495\ \text{mA}} = 4.04\ \text{k}\Omega$$

The voltage at the collector can be increased to 0.4 V and remain in the active mode. Therefore, R_C can increase to ≈ 5.9 kΩ and the collector current will remain unchanged.

$$R_{Cmax} = \frac{0.4\text{V} - -2.5\ \text{V}}{0.495\ \text{mA}} = 5.86\text{k}\Omega$$