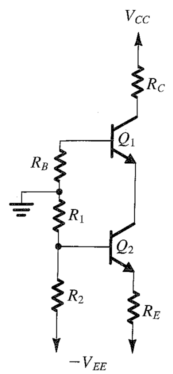

FIGURE P5.99

***D5.100** For the circuit in Fig. P5.100, assuming all transistors to be identical with β infinite, derive an expression for the output current I_O, and show that by selecting

$$R_1 = R_2$$

and keeping the current in each junction the same, the current I_O will be

$$I_O = \frac{\alpha V_{CC}}{2R_E}$$

which is independent of V_{BE}. What must the relationship of R_E to R_1 and R_2 be? For $V_{CC} = 10$ V and assuming $\alpha \simeq 1$ and $V_{BE} = 0.7$ V, design the circuit to obtain an output current of 0.5 mA. What is the lowest voltage that can be applied to the collector of Q_3?

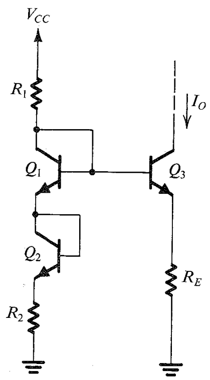

FIGURE P5.100

D5.101 For the circuit in Fig. P5.101 find the value of R that will result in $I_O \simeq 2$ mA. What is the largest voltage that can be applied to the collector? Assume $|V_{BE}| = 0.7$ V.

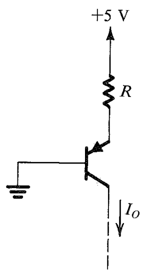

FIGURE P5.101

SECTION 5.6: SMALL-SIGNAL OPERATION AND MODELS

5.102 Consider a transistor biased to operate in the active mode at a dc collector current I_C. Calculate the collector signal current as a fraction of I_C (i.e., i_c/I_C) for input signals v_{be} of +1 mV, −1 mV, +2 mV, −2 mV, +5 mV, −5 mV, +8 mV, −8 mV, +10 mV, −10 mV, +12 mV, and −12 mV. In each case do the calculation two ways:

(a) using the exponential characteristic, and
(b) using the small-signal approximation.

Present your results in the form of a table that includes a column for the error introduced by the small-signal approximation. Comment on the range of validity of the small-signal approximation.

5.103 An *npn* BJT with grounded emitter is operated with $V_{BE} = 0.700$ V, at which the collector current is 1 mA. A 10-kΩ resistor connects the collector to a +15-V supply. What is the resulting collector voltage V_C? Now, if a signal applied to the base raises v_{BE} to 705 mV, find the resulting total collector current i_C and total collector voltage v_C using the exponential i_C–v_{BE} relationship. For this situation, what are v_{be} and v_c? Calculate the voltage gain v_c/v_{be}. Compare with the value obtained using the small-signal approximation, that is, $-g_m R_C$.

5.104 A transistor with $\beta = 120$ is biased to operate at a dc collector current of 1.2 mA. Find the values of g_m, r_π, and r_e. Repeat for a bias current of 120 μA.

5.105 A *pnp* BJT is biased to operate at $I_C = 2.0$ mA. What is the associated value of g_m? If $\beta = 50$, what is the value of the small-signal resistance seen looking into the emitter (r_e)? Into the base (r_π)? If the collector is connected to a 5-kΩ load, with a signal of 5-mV peak applied between base and emitter, what output signal voltage results?

D5.106 A designer wishes to create a BJT amplifier with a g_m of 50 mA/V and a base input resistance of 2000 Ω or more. What emitter-bias current should he choose? What is the minimum β he can tolerate for the transistor used?

5.107 A transistor operating with nominal g_m of 60 mA/V has a β that ranges from 50 to 200. Also, the bias circuit, being less than ideal, allows a ±20% variation in I_C. What are the extreme values found of the resistance looking into the base?

5.108 In the circuit of Fig. 5.48, V_{BE} is adjusted so that $V_C = 2$ V. If $V_{CC} = 5$ V, $R_C = 3$ kΩ, and a signal $v_{be} = 0.005 \sin \omega t$ volts is applied, find expressions for the total instantaneous quantities $i_C(t)$, $v_C(t)$, and $i_B(t)$. The transistor has $\beta = 100$. What is the voltage gain?

***D5.109** We wish to design the amplifier circuit of Fig. 5.48 under the constraint that V_{CC} is fixed. Let the input signal $v_{be} = \hat{V}_{be} \sin \omega t$, where $\hat{V}_{be}$ is the maximum value for acceptable linearity. For the design that results in the largest signal at the collector, without the BJT leaving the active region, show that

$$R_C I_C = (V_{CC} - 0.3 - \hat{V}_{be}) \Big/ \left(1 + \frac{\hat{V}_{be}}{V_T}\right)$$

and find an expression for the voltage gain obtained. For $V_{CC} = 5$ V and $\hat{V}_{be} = 5$ mV, find the dc voltage at the collector, the amplitude of the output voltage signal, and the voltage gain.

5.110 The following table summarizes some of the basic attributes of a number of BJTs of different types, operating as amplifiers under various conditions. Provide the missing entries.

Transistor	a	b	c	d	e	f	g
α	1.000					0.90	
β		100		∞			
I_C (mA)	1.00		1.00				
I_E (mA)		1.00				5	
I_B (mA)			0.020				1.10
g_m (mA/V)							700
r_e (Ω)				25	100		
r_π (Ω)					10.1 kΩ		

(*Note:* Isn't it remarkable how much two parameters can reveal?)

5.111 A BJT is biased to operate in the active mode at a dc collector current of 1.0 mA. It has a β of 120. Give the four small-signal models (Figs. 5.51 and 5.52) of the BJT complete with the values of their parameters.

5.112 The transistor amplifier in Fig. P5.112 is biased with a current source I and has a very high β. Find the dc voltage at the collector, V_C. Also, find the value of g_m. Replace the transistor with the simplified hybrid-π model of Fig. 5.51(a) (note that the dc current source I should be replaced with an open circuit). Hence find the voltage gain v_c/v_i.

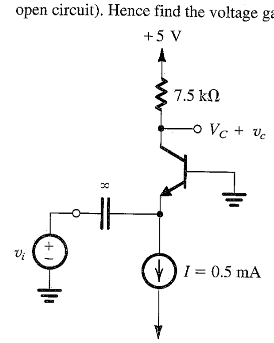

FIGURE P5.112

5.113 For the conceptual circuit shown in Fig. 5.50, $R_C = 2$ kΩ, $g_m = 50$ mA/V, and $\beta = 100$. If a peak-to-peak output voltage of 1 V is measured at the collector, what ac input voltage and current must be associated with the base?

5.114 A biased BJT operates as a grounded-emitter amplifier between a signal source, with a source resistance of 10 kΩ, connected to the base and a 10-kΩ load connected as a collector resistance R_C. In the corresponding model, g_m is 40 mA/V