EE 321 - Exam 3

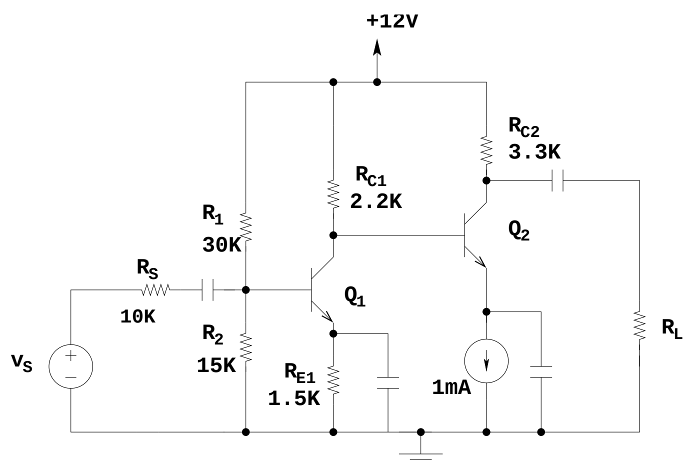
November 15, 2002

Name: ____

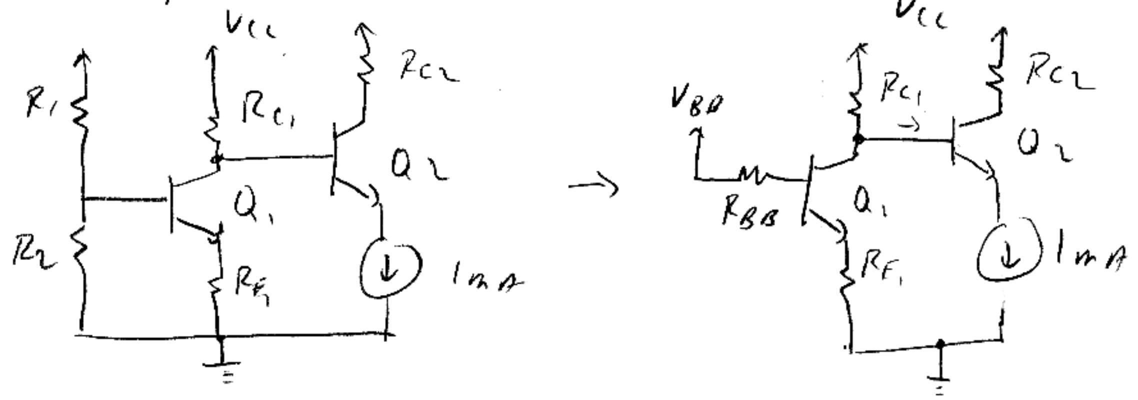
Closed book. One page of notes and a calculator are allowed. Show all work. Partial credit will be given. No credit will be given if an answer appears with no supporting work.

For all the circuits below, assume the capacitors are large so they block DC and pass all signals of interest.

1. In the circuit below, both transistors have $\beta = 100$.
   (a) Find the bias voltages V_{B1}, V_{C1}, V_{E1}, V_{C2} and V_{E2}.
   (b) Find the bias collector currents I_{C1} and I_{C2}.
   (c) Find the small-circuit parameters for Q_2: r_π, r_e and g_m.



1. (a) DC – Capacitors are open circuits



$$V_{BB} = \frac{R_2}{R_1+R_2} V_{CC} = \frac{15k}{15k+30k} 12V = 4V$$

$$R_{BB} = R_1 \parallel R_2 = \frac{(15k)(30k)}{(15k+30k)} = 10k$$

KVL through Q_1: $V_{BB} = I_{B_1} R_{BB} + V_{BE_1} + (\beta+1) I_{B_1} R_{E_1}$

$$I_{B_1} = \frac{V_{BB} - V_{BE}}{R_{BB} + (\beta+1) R_{E_1}} = \frac{4V - 0.7V}{10k + (101)(1.5k)} = 0.020\ mA$$

$I_{E_1} = (\beta+1) I_{B_1} = 2.1\ mA$

$I_{C_1} = \beta I_{B_1} = 2.0\ mA$

$V_{E_1} = I_{E_1} R_{E_1} = 3.1\ V$

$V_{B_1} = V_{E_1} + V_{BE_1} = 3.1V + 0.7V = 3.8V$

$V_{C_1} = V_{CC} - R_{C_1}(I_{C_1} - I_{B_2})$ Don't know I_{B_2} yet

$I_{E_2} = 1mA$

$I_{B_2} = I_{E_2}/\beta+1 = 0.0099\ mA$

$I_{C_2} = \alpha I_{E_2} = 0.99\ mA$

$V_{C_1} = V_{CC} - R_{C_1}(I_{C_1} - I_{B_2}) = 7.5\ V$

$V_{B_2} = V_{C_1} = 7.5V$

$V_{E_2} = V_{B_2} - V_{BE_2} = 7.5V - 0.7V = 6.7V$

$V_{C_2} = V_{CC} - I_{C_2} R_{C_2} = 8.7V$

V_{B_1}	$= 3.8V$
V_{C_1}	$= 7.5V$
V_{E_1}	$= 3.1V$
V_{B_2}	$= 7.5V$
V_{C_2}	$= 8.7V$
V_{E_2}	$= 6.7V$
V_{CE_1}	$= 4.4V$ Active
V_{CE_2}	$= 2.0V$ Active

(b) From (a) $I_{C_1} = 2.0\,mA$

$I_{C_2} = 0.99\,mA$

(c) $r_{\pi_2} = \frac{V_T}{I_{B_2}} = \frac{25\,mV}{0.0099\,mA} = 2.5\,k\Omega$

$r_{e_2} = \frac{V_T}{I_{E_2}} = \frac{25\,mV}{1\,mA} = 25\,\Omega$

$g_{m_2} = \frac{I_{C_2}}{V_T} = \frac{0.99\,mA}{25\,mV} = 40\,mA/V$

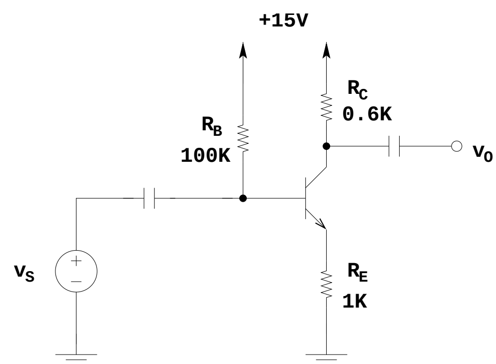
2. The BJT in the circuit below has $\beta = 100$. You may ignore r_o for this problem.

   (a) Find a value for r_e.

   (b) Draw the small-circuit equivalent model.

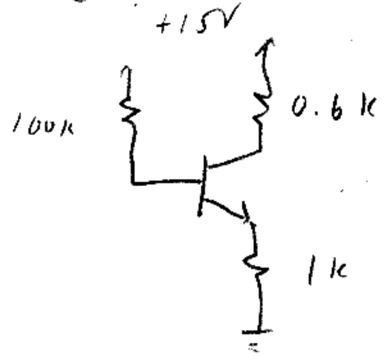
   (c) Calculate the voltage gain of the circuit.

   (d) Find the input resistance of the circuit.



2. (a) $r_e = \frac{V_T}{I_E}$, so need I_E

DC



$$V_{CC} = I_B R_B + V_{BE} + (\beta+1) I_B R_E$$

$$I_B = \frac{V_{CC} - V_{BE}}{R_B + (\beta+1) R_E} = \frac{15\,V - 0.7\,V}{100k + (101)(1k)} = 0.071\,mA$$

$$I_E = (\beta+1) R_E = 7.2\,mA$$

$$V_E = I_E R_E = 7.2\,V$$

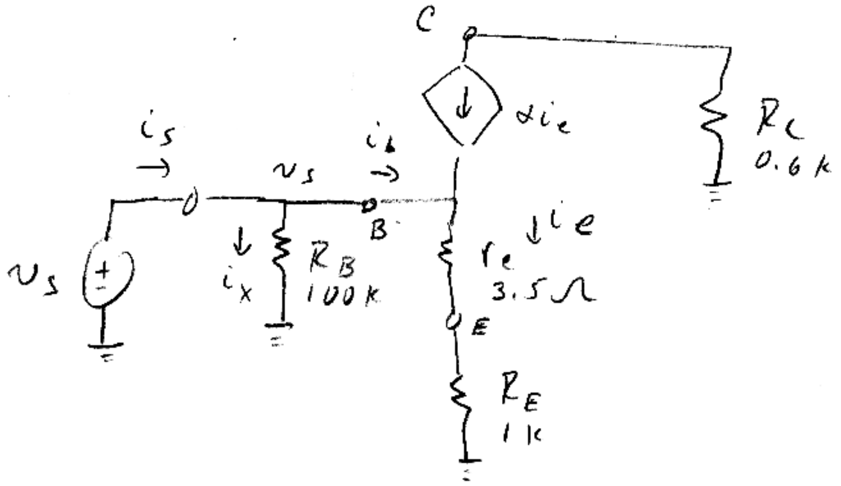
$$I_C = \beta I_B = 7.1\,mA$$

$$V_C = V_{CC} - I_C R_C = 10.7\,V$$

$V_{CE} = V_C - V_E = 3.5\,V$, so Q is active

$$r_e = \frac{V_T}{I_E} = \frac{25\,mV}{7.2\,mA} = 3.5\,\Omega$$

(b) Small signal - use T model (because we have R_E)



(c) $v_o = -\alpha i_e R_C$

$$i_e = \frac{v_s}{r_e + R_E}$$

$$v_o = \frac{-\alpha R_C}{r_e + R_E} v_s$$

$$\frac{v_o}{v_s} = \frac{-\alpha R_C}{r_e + R_E} = 0.59 \text{ V/V}$$

(d) $R_i = \dfrac{v_s}{i_s}$

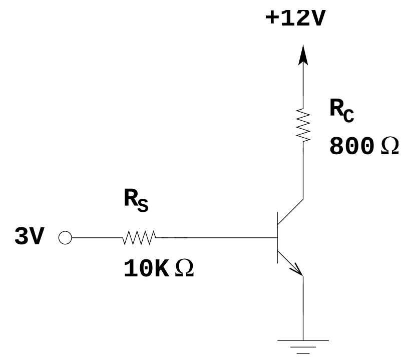
$$i_s = i_x + i_b \qquad i_x = \frac{v_s}{R_B} \qquad i_b = \frac{i_e}{\beta+1} = \frac{v_s}{(\beta+1)(r_e+R_E)}$$

$$i_s = i_x + i_b = \frac{v_s}{R_B} + \frac{v_s}{(\beta+1)(r_e+R_E)}$$

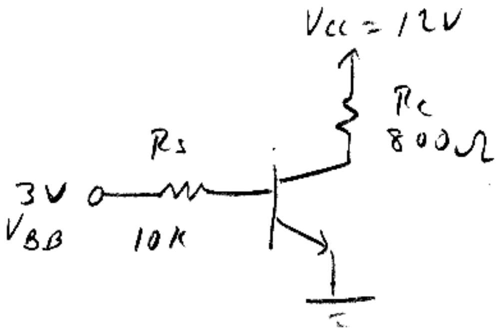
$$R_i = \frac{v_s}{i_s} = \frac{v_s}{\frac{v_s}{R_B} + \frac{v_s}{(\beta+1)(r_e+R_E)}} = \frac{1}{\frac{1}{R_B} + \frac{1}{(\beta+1)(r_e+R_E)}}$$

$$R_i = R_B \parallel (\beta+1)(r_e+R_E) = 100\text{k} \parallel (101)(1.035\text{k}) = 51\text{ k}$$

(e) Find the value of β needed for the BJT in the circuit below such that the BJT is just on the edge of saturation – i.e., $I_B = I_{B_{EOS}}$.



3.



$$I_{C_{sat}} = \frac{V_{CC} - V_{CE\,sat}}{R_C} = \frac{12V - 0.2V}{0.8k} = 15\,mA$$

$$V_{BB} = I_B R_S + V_{BE} \Rightarrow I_B = \frac{V_{BB} - V_{BE}}{R_S} = \frac{3V - 0.7V}{10k}$$

$$= 0.23\,mA$$

$$I_{B_{EOS}} = \frac{I_{C_{sat}}}{\beta} \Rightarrow \beta = \frac{I_{C_{sat}}}{I_{B_{EOS}}} = \frac{15\,mA}{0.23\,mA} = 64$$

$\beta = 6v \Rightarrow$ Q just saturated