1. The figure shows the ac signal circuit of a cascade common-emitter amplifier. For each BJT, it is given that $I_E = 1.5\,\text{mA}$, $\alpha = 0.99$, $\beta = 99$, $r_x = 20\,\Omega$, $r_0 = \infty$, and $V_T = 0.025\,\text{V}$. The circuit element values are $R_S = 1\,\text{k}\Omega$, $R_{E1} = R_{E2} = 47\,\Omega$, $R_{C1} = R_{C2} = 10\,\text{k}\Omega$.

(a) Looking out of the base of $Q_2$, use the Norton collector circuit of $Q_1$ to show that

$$v_{tb2} = -i_c R_c = -134.03v_s \quad R_{tb2} = R_{C1} = 10\,\text{k}\Omega$$

(b) Use the Norton collector circuit for $Q_2$ to show that

$$v_o = 8097v_s \quad r_{out} = R_{C2} = 10\,\text{k}\Omega$$

(c) Show that

$$r_{in} = r_{ib1} = 6.387\,\text{k}\Omega$$

(d) If a resistor $R_L = 1\,\text{k}\Omega$ is connected from output to ground, show that the new gain is reduced by a factor $R_L / (r_{out} + R_L)$ to the value $v_o/v_s = 736.1$ and that the dB decrease in gain is $20.83\,\text{dB}$.

2. The ac signal circuit of a common-base amplifier driving a common-collector amplifier is shown. For each BJT, it is given that $I_E = 1.5\,\text{mA}$, $\alpha = 0.99$, $\beta = 99$, $r_x = 20\,\Omega$, $r_0 = \infty$, and $V_T = 0.025\,\text{V}$. The circuit element values are $R_S = 50\,\Omega$, $R_C = 10\,\text{k}\Omega$, $R_E = 1\,\text{k}\Omega$. ??
(a) Looking out of the base of $Q_2$ use the Norton collector circuit of $Q_1$ to show that
\[ v_{tb2} = 148.06v_s \quad R_{tb2} = 10 \, \text{k}\Omega \]

(b) Use the simplified T model for $Q_2$ to show that
\[ v_o = 132.56v_s \quad r_{out} = r_{ie2}\|R_E = 104.638 \, \Omega \]

(c) Use the simplified T model for $Q_1$ to show that
\[ r_{in} = r_{ie1} = 16.867 \, \Omega \]

(d) If a resistor $R_L = 1 \, \text{k}\Omega$ is connected from output to ground, show that the new gain is reduced by the factor $R_L/(r_{out} + R_L)$ to the value $v_o/v_s = 120.01$ and the dB decrease in gain is 0.864 dB. Note that the gain does not change nearly as much as it did in problem 1. Explain.

3. The figure shows a cascade common-collector amplifier, also called a Darlington connection. For each BJT, it is given that $\alpha = 0.99$, $\beta = 99$, $r_x = 20 \, \Omega$, $r_0 = \infty$, and $V_T = 0.025 \, \text{V}$. The emitter current in $Q_2$ is $I_{E2} = 10 \, \text{mA}$. The circuit element values are $R_S = 10 \, \text{k}\Omega$ and $R_E = 100 \, \Omega$.

4. The figure shows a common-collector stage driving a common-base stage. For each BJT, it is given that $I_E = 1.5 \, \text{mA}$, $\alpha = 0.99$, $\beta = 99$, $r_x = 20 \, \Omega$, $r_0 = \infty$, and $V_T = 0.025 \, \text{V}$. The circuit element values are $R_S = 1 \, \text{k}\Omega$, $R_E = 100 \, \Omega$, $R_C = 10 \, \text{k}\Omega$. 
(a) Use the simplified T model for $Q_1$ to show that

$$v_{te2} = v_s \quad R_{te2} = R_E + r_{ie1} = 126.87 \, \Omega$$

(b) Use the Norton collector circuit of $Q_2$ to show that

$$v_o = 68.88v_s \quad r_{out} = R_C = 10 \, k\Omega$$

(c) Show that

$$r_{in} = r_{ib1} = 13.37 \, k\Omega$$