I. For the circuit shown below, assume the diodes to be ideal and find the values of the labeled voltages and currents.

\[ I = I_1 + I_2 \]

\[ \frac{V_0 - V_X}{2.5} = \frac{V_X}{5} + \frac{V_X + 5}{10} \]

\[ 4 - \frac{4}{10} V_X = \frac{V_X}{5} + \frac{V_X}{10} + \frac{1}{2} \]

\[ \frac{4}{2} = V_X \left[ \frac{1}{5} + \frac{1}{10} + \frac{4}{10} \right] \]

\[ \rightarrow V_X = 5V \]
II. Measurements on the circuit below gave the values of the voltage indicated on the figure. Find the value of the $\beta$ for the transistor. Also, indicate which way the emitter, base, and collector currents are flowing in the transistor.

\[
I_B = \frac{4.3 - 2.3}{20} = 0.1 \text{ mA}
\]

\[
I_C = 9.9 \text{ mA}
\]

\[
I_E = \frac{2.3}{0.23} = 10 \text{ mA}
\]

\[
\beta = \frac{I_C}{I_B} = \frac{9.9}{0.1} = 99
\]
II. (25 pts) For the circuit below, assume a $\beta = 100$ and $V_{EB} = 0.7$. Calculate the values of $V_B$, $V_C$, $I_E$, $I_B$, $I_C$.

**Loop Equation:**

$$10 - 6.8(\beta+1)I_B - 0.7 - 100I_B - 2.5 = 0$$

$\beta = 100$

$\Rightarrow I_B = 0.085 mA$

$I_E = 0.87 mA \quad I_C = 0.86 mA$

$V_E = 10 - 6.8(\beta+1)I_B = 4.06 V$

$V_E = 10 - 6.8I_E = 4.06 V$

$V_B = 3.36 V (V_E - 0.7)$

$V_C = -10 + 0.86 \cdot 10 = -1.4 V$
I: (25 pts) Assume the diodes below are ideal and calculate ALL the voltages and currents as requested. For full credit, indicate next to EACH DIODE which one is ON or OFF.

\[
\frac{V_x + 10}{5} = \frac{10 - V_x}{30} + \frac{(-V_x)}{10}
\]

\[\Rightarrow 6(V_x + 10) = 10 - V_x - 3V_x
\]

\[-10V_x = -50\]

\[\Rightarrow V_x = -5V\]
I. (25 pts) Assuming that the diodes in the circuit below are ideal, find the values of the labeled currents and voltages. For each diode, indicate if it is ON or OFF.

(a) 

(b) 

\[ I = \frac{6}{10k\Omega} = 0.6\,mA \]

\[ I = \frac{3-1}{2k\Omega} = 1mA \]
II. (25 pts) In the circuit shown below, find the emitter, base, and collector voltages and currents. Assume $|V_{BE}| = 0.7 \text{ V}$ and $\beta = 30$.

\[ V_B = 3 \text{ V} \]
\[ V_E = V_B + 0.7 = 3.7 \text{ V} \]
\[ I_E = \frac{V_E}{R_E} = \frac{3.7}{47} = 0.089 \text{ mA} \]
\[ I_C = \beta I_E = 30 \times 0.089 \text{ mA} = 4.93 \text{ mA} \]
\[ V_C = V_B - I_C R_C = 3 - 4.93 \times 2 = 4.22 \text{ V} \]
\[ I_B = \frac{I_C}{\beta} = \frac{4.93}{30} = 0.164 \text{ mA} \]
III. (20 pts) For the transistor shown below, find the values of the labeled node voltages and currents. Assume $\beta$ is very large (infinity) and that $|V_{EB}| = 0.7 \, \text{V}$.

\[ \begin{align*}
I_C &= \frac{5 - 0.7}{2.2} = 1.955 \, \text{mA} \\
I_E &= \frac{5 - 0.7}{2.2} = 1.955 \, \text{mA} \\
I_C &= 1.955 \, \text{mA} \\
V_C &= 5 - 1.6 \times 1.955 \, \text{mA} = 1.872 \, \text{V} \\
V_E &= 0 - 0.7 = -0.7 \, \text{V} \\
I_B &= 2 \, \text{mA} \\
V_B &= 5 \, \text{V} \\
V_E &= 0 \, \text{V} \\
V_C &= 5 \, \text{V} \\
\text{because } \gamma = 1 \text{ and } \beta = \infty
\end{align*} \]
IV. (30 pts) For the circuit shown below,

- Is it a common-emitter, common-base, or common-collector configuration?
- If the signal source is set to zero, find the DC emitter current (Use the technique of the loop equation) to solve for $I_E$. Assume $\beta = 100$.
- Use the hybrid-$\pi$ model and draw the AC (small signal) equivalent circuit of this amplifier network.
- Neglect the effect of $r_o$ in the AC equivalent circuit and find the value of the input resistance $R_m$ as indicated on the diagram below.
- Finally, calculate the voltage gain $v_o/v_{sig}$.

\[ R_m = 3.3 \, \text{k}\Omega \]

\[ I_B = \frac{I_E}{(\beta+1)} \quad \beta = 100 \]

\[ I_E = \frac{5-0.7}{\frac{3.3 \, \text{k}\Omega + \frac{100 \, \text{k}\Omega}{\beta+1}}}{3.3 \, \text{k}\Omega + \frac{100 \, \text{k}\Omega}{\beta+1}} \]

\[ I_E = \frac{4.3}{3.3 \, \text{k}\Omega + \frac{100 \, \text{k}\Omega}{101}} \approx 1 \, \text{mA} \]
\[ i_e = i_H + g_m V_H = \frac{V_H}{R_H} + g_m V_H = (1 + g_m R_H) \frac{V_H}{R_H} \]

\[ V_0 = (3.3\, k\Omega / 1\, k\Omega) i_e \]

\[ R_{in} = \frac{V_E}{i_H} = \frac{V_H + V_0}{i_H} = R_H + (3.3\, k\Omega / 1\, k\Omega) \frac{i_H}{i_H} \]

\[ R_{in} = (3.3\, k\Omega / 1\, k\Omega) + (2.5\, k\Omega) = 80\, k\Omega \]

Same as obtained from reflection coefficient \( \rho \)

\[ N_0 = (3.3\, k\Omega / 1\, k\Omega) \frac{i_H}{i_H} \]

\[ \frac{N_0}{N_{sig}} = \frac{N_0}{N_{sig}} \left( \frac{N_{sig}}{N_H + N_0} \right) \frac{R_{in}}{R_{in} + 100\, k\Omega} = \left[ 1 + \frac{N_0}{N_{sig}} \right] \frac{R_{in}}{R_{in} + 100\, k\Omega} \]

\[ \frac{V_0}{N_{sig}} = \frac{3}{80} = 0.4 \]

\[ V_0 = (3.3\, k\Omega / 1\, k\Omega) \frac{V_H}{R_H} \]

\[ \frac{N_0}{N_H} = \frac{(3.3\, k\Omega / 1\, k\Omega) V_H}{R_H} \]

\[ \frac{N_0}{N_H} = 31 \]
1. (25 pts) A single measurement on the circuit shown in the figure below provides an emitter voltage $V_E = 1$ V. Assuming that $|V_{BE}| = 0.7$ V, calculate the values of $V_B$, $V_C$, $I_B$, $I_E$, $I_C$, $\beta$, and $\alpha$.

\[ I_E = \frac{5 - 1}{5} = 0.8 \text{ mA} \]

\[ V_B = \frac{0.3}{5} = 0.06 \text{ V} \]

\[ V_C = -5 + 0.785 \times 5 = -1.075 \text{ V} \]

\[ I_B = \frac{0.3}{200} = 0.015 \text{ mA} \]

\[ I_C = I_E - I_B = 0.8 - 0.015 = 0.785 \text{ mA} \]

\[ \beta = \frac{I_C}{I_B} = \frac{0.785}{0.015} = 52.3 \]

\[ \alpha = \frac{I_C}{I_E} = \frac{0.785}{0.8} = 0.98 \]
2. (25 pts) The Pnp transistor in the circuit below has a $\beta$ of 50.

- Find the value of $R_C$ to have a $V_C = +5 \text{ V}$.
- What happens to the value of $V_C$ if the $\beta$ of the transistor is 100?

\[ I_B = \frac{9.3}{100} \]

\[ I_C = \frac{9.3}{100} \times \beta \]

For $V_C = 5\text{ V}$, $\beta \frac{R_C}{9.3 \times 50} = 1.08\text{ k}\Omega$

with $\beta = 50 \rightarrow R_C = \frac{500}{9.3 \times 50} = 1.08\text{ k}\Omega$

For $\beta = 100$

\[ V_C = \frac{9.3}{100} \times \beta \frac{R_C}{100} = \frac{9.3}{100} \times 1.08 = 10.04\text{ V} \]

\[\Rightarrow V_{BC} = 9.3 - 10.04 = -0.74\text{ V} \]

Since $V_{BC} < -0.4\text{ V}$

The transistor saturates.
III. (Chapter 4) For the circuit shown below, find all node voltages, i.e., the dc voltage at the emitter, base, and collector of both transistors. Assume $\beta$ is equal to 99 for both transistors. Hint: Use thevenin equivalent and the "loop equation", starting with the left transistor.

\[ I_{C1} = \alpha_1 I_{E1} = 0.159 \text{ mA} \]

\[ I_{E1} = \frac{9 - 6.57 - 0.7}{10 + \left(\frac{100}{99 + 1}\right)} = 0.161 \text{ mA} \]

\[ V_{E1} = 9 - 0.161 \times 70 = 4.59 \text{ V} \]

\[ V_{E2} = 7.39 - 0.7 = 6.69 \text{ V} \]

\[ I_{C2} = 0.99 \times 0.81 = 0.804 \text{ mA} \]

\[ I_{E2} = \frac{1.59 - 0.7}{1 + \frac{10}{99 + 1}} = 0.81 \text{ mA} \]

\[ V_{E2} = 0.81 + 0.7 = 1.51 \text{ V} \]

\[ V_{E2} = 0.81 \times 1 = 0.81 \text{ V} \]
3. (25 pts) For the circuit shown below

- Draw the small signal (AC) equivalent circuit of the entire circuit using the T-model equivalent circuit for the transistor (neglect the effect of $r_0$).
- Give an analytical expression for the input resistance $R_{in}$?
- Give an analytical expression for the voltage gain $\frac{v_o}{v_{\text{sig}}}$ and calculate its numerical value assuming $\alpha = 0.99$, $R_e = 50 \, \Omega$
II. (Chapter 4) For the emitter follower below, the BJT has a value of $\beta$ equal to 50. Find (a) the dc values of $I_E$, $V_E$, and $V_B$, and (b) the input resistance $R_i$. Assume $r_o$ is equal to infinity. Then, use the T-model for the transistor and draw the small signal equivalent circuit for the amplifier below. Finally, calculate the voltage gain $v_o/v_i$.

\[ I_E = \frac{9 - 0.7}{1 + \frac{100}{1000}} = 2.8 \text{ mA} \]
\[ V_E = 2.8 \text{ V} \]
\[ I_B = 0.055 \text{ mA} \]

\[ V_B = 9 - 100 \times 0.055 = 3.5 \text{ V} \]

Resistance reflection rule:
\[ R_i = \frac{100 \text{ k} \Omega}{(\beta+1)} \left( \frac{1}{\beta} + \frac{1}{1.11} \right) \]
\[ R_i = 8.93 \text{ k} \Omega \]

\[ \frac{N_o}{N_s} = \frac{N_B}{N_s} = \left( \frac{R_i}{R_o + R_i} \right) \left( \frac{1/\beta + 1/1.11}{1/\beta} \right) + 5 \]

\[ \beta = 50 \rightarrow \frac{N_o}{N_s} = \left( \frac{2.0.28}{0.5 + 20.28} \right) \frac{0.5}{0.5 + 0.0089} \]
\[ = \left( 0.66988 \right) \left( 0.9925 \right) = 0.658 \text{ V/V} \]
4. (25 pts) In the circuit amplifier below, the signal source is directly connected (i.e., without the use of a coupling capacitor) to the transistor base. Assume the $\beta$ is equal to 100 and neglect the effect of $r_0$ in both the DC and AC analyses.

- (a) Is this configuration a common-emitter, common-base, or common collector amplifier? Circle the correct answer.

- (b) Assuming that the DC component of the signal $v_{sig}$ is zero, find the DC emitter current $I_E$. (Write loop equation). Assume $V_{EB} = 0.7\, V$

- (c) Draw the small AC equivalent circuit of the amplifier using the T-model for the transistor.

- (d) Using the equivalent circuit drawn in part (c), give an expression for the output resistance, $R_{out}$, as shown on the diagram.

\[ 5 - 3.3 \, I_E - 0.7 - 100 \, I_B = 0 \quad \Rightarrow \quad I_B = \frac{I_E}{\beta + 1} \]

\[ \rightarrow I_E = \frac{5 - 0.7}{3.3 + \frac{100}{101}} = 1\, mA \]

\[ \rightarrow R_C = \frac{V_I}{I_E} = 25\, \Omega \]
\( \frac{i_x}{N_x} = \frac{1}{R_x} = \frac{1}{R_{out}} = \frac{1}{3.3} + \frac{1}{R_e + \frac{100}{B+1}} \)

\( R_{out} = R_x = \left[ \frac{3.3 k\Omega}{// \left[ R_e + \frac{100}{B+1} \right]} \right] \)

\( R_{out} = 0.778 k\Omega \)
II. (20 pts) For the circuit shown below, find the values of the current supply $I$ and the resistance $R_B$ to bias the BJT so that the collector current $I_C = 3\text{mA}$ and $V_C = 1.5\text{ V}$. Assume $\beta = 90$.

\[ I_C = 3\text{mA} \]

\[ I_B = \frac{I_C}{\beta} = \frac{3\text{mA}}{90} = 0.033\text{mA} \]

\[ V_C = R_B I_B + 0.7 \]

\[ V_C = 1.5\text{V} \text{ given} \]

\[ R_B = \frac{V_C - 0.7}{I_B} = 24.2\text{ k}\Omega \]

\[ I_E = \frac{I_C}{\alpha} = 3.03\text{mA} \]

\[ I = I_C - I_B = I_E \]

\[ I = 3.03\text{mA} \]
III: (25 pts) For the circuit shown below, find the values of the assuming that the $\beta$ of the transistor is 100. The transistor is a Pn 0.7 V.

\[ V_{\text{Th}} = -5 + \left( \frac{150}{150 + 91} \right) \]
\[ = 1.22 \text{V} \]

\[ R_{\text{Th}} = \left( \frac{91}{150} \right) \text{k}\Omega = 56.6 \text{k}\Omega \]

\[ 5 - V_{\text{Th}} = 3.3 I_E (\text{mA}) + 0.7 + R_{\text{Th}} I_B (\text{mA}) \]

\[ I_E = \frac{5 - V_{\text{Th}} - 0.7}{\left( \frac{R_{\text{Th}}}{\beta + 1} \right)} \]
\[ = \frac{3.08 \text{mA}}{3.87} \]

\[ V_E = 5 - 3.3 I_E = 2.37 \text{V} \]
\[ V_B = 1.67 \text{V} \]

\[ I_C = \beta I_B = 0.79 \text{mA} \]
\[ I_E = \alpha I_C \]
\[ V_C = -5 + 5.1 I_C = -0.97 \text{V} \]
IV. (30 pts) For the two circuits shown below:

- (a) Specify which type of amplifier they are, i.e., common-emitter, common-base, or common-collector configuration.
- (b) For the first amplifier, draw the small ac equivalent circuit using the T-model to represent the BJT. Neglect $r_0$ in the equivalent circuit.
- (c) Repeat (b) for the second circuit using the hybrid-$\pi$ model for the BJT. Include the resistance $r_0$ in this diagram.

The capacitors with an $\infty$ label under them can be replaced by short circuits in the equivalent circuit diagram.
III. In the follower circuit below, the transistor $Q_1$ has a $\beta = 20$, and transistor $Q_2$ has a $\beta = 200$. Neglect the effect of $r_0$ in both transistors, use $V_{BE} = 0.7V$ and

- Find the dc emitter current of $Q_1$ and $Q_2$. Also find the dc voltages $V_{B1}$ and $V_{B2}$.

- If a load resistor $R_L = 1k\Omega$ is connected to the output terminal, find the voltage gain from the base to the emitter of $Q_2$, $v_{b_2}/v_{b_2}$, and find the input resistance looking into the base of $Q_2$, $R_{ib_2}$. (Hint: consider $Q_2$ as an emitter follower fed by a voltage $v_{b_2}$ at its base).

- Replacing $Q_2$ with its input resistance found in the previous step, analyze the circuit of the emitter follower $Q_1$ to determine its input resistance $R_i$, and the gain from its base to its emitter, $v_{e_1}/v_{b_1}$.

\[ I_{E2} = 2.0 mA \]
\[ I_{E1} = 20 mA + I_{B2} = 20 mA + \frac{2000}{201} = 30 mA \]
\[ V_{B1} = 4.5 - 0.5 \times 1.43 = 3.79V \]
\[ V_{B2} = 3.79 - 0.7 = 3.09V \]

\[ \frac{V_{N2}}{V_{N2}} = \frac{R_L}{R_L + R_e2} \]
\[ R_L = 1k \Omega; \quad R_e2 = \frac{25}{2} = 12.5 \Omega \Rightarrow \frac{V_{T}}{V_{N2}} = 0.988 \]
\[ R_{ib_2} = (B_2+1)(R_e2 + R_L) = 201 \times 1.0125 = 203.5 k\Omega \]

\[ \frac{V_{N1}}{V_{N1}} = \frac{R_{ib_2}}{R_{ib_2} + R_{e1}} \Rightarrow \left[ R_{e1} = \frac{V_{T}}{30 mA} = 83 \Omega \right] \Rightarrow \frac{V_{N1}}{V_{N1}} = 0.996V \]

\[ R_i = 10M \Omega // 1M \Omega // (B_1+1)(R_{e1}+R_{ib_2}) \]
\[ R_i = 1M \Omega // 4.29 \Omega = 0.448 \Omega \]
1. (20 pts) For the circuit shown below, assume the $\beta$ is infinite. Some measurements have been made on the circuit and the results are shown on the figure. Find the values of the labeled voltage and current. Assume that $V_{EB} = 0.7 \text{ V}$.
2. (20 pts) For the circuit shown below, measurements have produced the indicated voltages. Find the value of $\beta$ for that transistor.

\[ I_E = \frac{2.3V}{0.23} = 10mA \]

\[ I_B = \frac{4.3 - 2.3}{20} = 0.1mA \]

\[ I_C = I_E - I_B = 9.9mA \]

\[ \frac{I_C}{I_B} = \frac{9.9}{0.1} = 99 \]
3. (30 pts) In the circuit below, $v_s$ is a small sine wave with zero average value, i.e., there is no DC component to the input signal $v_s$.

- Is the configuration shown in the circuit below a common-emitter, common-base, or common-collector configuration. Circle your answer.
- Use the hybrid-$\pi$ model for the BJT and draw the AC equivalent circuit of the amplifier.
- Give an analytical expression for the input resistance, i.e., resistance $R_{in}$ looking into the base, as shown in the figure below.

\[
\begin{align*}
\text{\textbf{Expression}} & \quad \text{\textbf{Value}} \\
R_{in} & \quad (B+1) \left[ 2 \times 125 + 2 \times \frac{g_m}{125} \right]
\end{align*}
\]
4. (30 pts) In the circuit amplifier below, the signal source is directly connected (i.e., without the use of a coupling capacitor) to the transistor base. The input signal \( v_s \) is a small sine wave with zero average value, i.e., there is no DC component to the input signal \( v_s \). Assume the \( \beta \) of the transistor is equal to 120 and neglect the effect of \( r_0 \) in both the DC and AC analyses.

- (a) Is this configuration a common-emitter, common-base, or common collector amplifier? Circle the correct answer. [Blank]
- (b) Assuming that the DC component of the signal \( v_s \) is zero, find the DC emitter current \( I_E \) (Use the appropriate loop equation). Assume \( V_{EB} = 0.7 \) V.
- (c) Draw the small AC equivalent circuit of the amplifier using the T-model for the transistor.
- (d) Using the equivalent circuit drawn in part (c), give an expression for the output resistance, \( R_{out} \), as shown on the diagram.

\[
I_E = \frac{5 - 0.7}{3.3 + \frac{100}{\beta+1}} \approx 1.042 \text{ mA}
\]

\[
R_E = \frac{2.5}{1.042} = 2.4 \Omega
\]
The transistor below has a $\beta$ of 100. Also, $V_{CC}$ is 9 V, $R_1 = 27k\Omega$, $R_2 = 15k\Omega$, $R_E = 1.2k\Omega$, and $R_C = 2.2k\Omega$. Calculate the dc biasing current $I_E$. Assuming that $R_S = 10k\Omega$ and $R_L = 2k\Omega$, use the hybrid-$\pi$ model and draw the amplifier equivalent circuit. Calculate $R_i$, $g_m$, $A_v$, and $A_i$.

\[ I_E = \frac{V_{BB} - V_{BE}}{R_E + \frac{R_B}{\beta + 1}} \]

\[ V_{BB} = \frac{V_{CC}}{R_1 + R_2} = 9 \times \frac{15}{27 + 15} = \frac{3.21V}{27 + 15} \]

\[ R_B = R_1 \parallel R_2 = 9.64k\Omega \]

\[ I_E = 1.94mA \]

\[ \beta = \frac{I_C}{I_T} = \frac{76.8mA}{1.3k\Omega} \]

\[ R_T = R_B / \beta = 115k\Omega \]

\[ g_m = 76.8ma/V \]

\[ A_n = \frac{-g_m}{\beta} = -76.8mA/V \]

\[ A_i = \frac{I_O}{I_I} = \frac{V_{NO}/R_L}{V_{NO}/R_2} = -46.3 \text{ A/A} \]
I. (20 pts) Measurements on the circuit below produce the voltages indicated. Find the value of $\beta$ for this transistor.

\[ I_C = \frac{4.3}{1k\Omega} = 0.0043\ mA \]
\[ I_B = \frac{4.3}{200k\Omega} = 0.0215\ mA \]
\[ \beta = \frac{I_C}{I_B} = 93 \]
II. (20 pts) Consider the two amplifiers below and indicate if they are a common-emitter, common-base, or common-collector configuration. For the amplifier on the left, use the hybrid-π model for the BJT and draw the small signal equivalent circuit of the amplifier. Do the same for the amplifier on the right using the T-model for the BJT. For both amplifiers, include the resistance $r_0$ in the small signal equivalent circuit. You do not have to calculate any quantity, just show the small-signal equivalent circuit of the two amplifiers.
III. (30 pts) For the circuit shown below, draw the small signal equivalent circuit using a T-model for the BJT. Assume $\alpha = 0.99$. What is the input resistance $R_{in}$? Calculate the value of the voltage gain $v_o/v_{sig}$? Neglect $R_o$.

\[ R_{in} = \frac{N_E}{I_E} = \frac{50 \Omega}{0.5 \text{ mA}} = 100 \text{ $\Omega$} \]

\[ v_o = 0.99 i_E (R_C // R_L) \]

\[ v_{sig} = -(R_L + R_{sig}) i_E \]

\[ \frac{v_o}{v_{sig}} = 0.99 \frac{(R_C // R_L)}{R_L} = 0.99 \frac{5 \text{ k$\Omega$}}{50 \Omega} = 49.5 \text{ V/V} \]

\[ \frac{N_E}{N_{sig}} = 99 \]
IV. (30 pts) For the circuit shown below, draw the small signal equivalent circuit using the hybrid-π equivalent circuit for the BJT. Calculate the input resistance $R_{in}$ and the voltage gain $v_{0}/v_{sig}$.

Neglect $r_e$. $\beta = 100$

\[ \begin{align*}
    v_{H} &= \frac{V_T}{I_E} = 25 \text{ mV} \quad (101) \\
    \frac{v_{H}}{I_E} &= 0.1 \text{ mA} \\
    I_E &= 0.1 \text{ mA} \\
    I_C &= 0.099 \text{ mA} \\
    \eta &= \frac{I_C}{V_T} = 4 \text{ mS}^2
\end{align*} \]
IV. (30 pts) For the circuit shown below, draw the small signal equivalent circuit using the hybrid-$
pi$ equivalent circuit for the BJT. Calculate the input resistance $R_{in}$, and the voltage gain $v_o/v_{in}$. Note that $n_0 \cdot P_0 = 100$.

\[ N_E = (\beta + 1) N_H \]

\[ \frac{N_E}{N_B} = \frac{\beta + 1}{\beta + 1 + 250} \]

\[ i_b = i_b \left[ (\beta + 250 + \beta m_{EH}) \right] \]

\[ V_o = -\frac{g_m N_H}{1 + (\beta + 1) 250} \]

\[ R_{in} = \frac{1}{\beta m_{EH} + (\beta + 1) 250} \]

\[ \frac{V_o}{V_{in}} = \frac{N_E}{N_B} \]

\[ \frac{N_B}{N_{sig}} = \frac{N_E}{N_{sig}} \cdot \frac{N_H}{N_B} \]

\[ \frac{V_o}{V_{in}} = \left( -\frac{g_m 10 \Omega}{1 + (\beta + 1) 250} \right) \cdot \frac{R_{in}}{R_{in} + 250 \Omega} \]
ELECTRONICS I
November 10, 2008

I. (25 pts) Assuming that the diodes in the circuit below are ideal, find the values of the labeled currents and voltages. For each diode, indicate if it is ON or OFF.

Assume all ON

$V_1 = 9V + V = 8V$

$D_2$ and $D_3$ cannot both be on
$D_5$ and $D_6$ cannot both be on

Try $D_2$, $D_5$ - ON; $D_3$, $D_6$ - OFF
No, then $D_3$, $D_6$ are forward-biased,

$D_3$, $D_6$ - ON; $D_2$, $D_5$ - OFF

$I_1 = \frac{12V - 8V}{3\,k\Omega} = 2mA$
$I_2 = 0A$
$I_3 = 2mA - 1mA = 1mA$
$I_5 = \frac{8V - 4V}{4\,k\Omega} = 1mA$
$I_7 = \frac{4V}{8k\Omega} = 0.5mA$
$I_6 = 1mA - 0.5mA = 0.5mA$
$V_1 = 8V$

$I_5 = 0A$
II. (20 pts) For the transistor below, find the values of the labeled node voltages. Assume $\beta = 100$ and $V_{EB} = 0.7$ V (Pnp transistor).

\[ \alpha = \frac{\beta}{\beta + 1} = 0.99 \]

\[ I_C = \frac{8 - (-10)}{2k\Omega} = \frac{18}{2k\Omega} = 1mA \]

\[ I_B = \frac{I_C}{\beta} = \frac{1mA}{100} = 10uA \]

\[ I_E = \frac{I_C}{\alpha} = 1.01mA \]

\[ V = 1V + I_B(10k\Omega) = 1V + 10uA \times 10k\Omega = 1.1V \]

[Diagram of transistor circuit with labeled voltages and currents]
III. (25 pts) In the circuit shown below, find the emitter, base, and collector voltages and currents by first replacing the 12 V supply and the two leftmost resistors by their Thevenin equivalent. Then, use the "Loop equation technique" to calculate the current $I_E$. What is the value of the collector voltage $V_C$?

Assume $V_{BE} = 0.7$ V and $\beta = 100$. You will get no credit if you just give an equation for $I_E$ without showing where it is coming from (no rabbit out of the hat!).

$$V_1 = 12 \left( \frac{30k}{60k+10k} \right) = 9V$$

$$R = 20k = \frac{30k \times 164k}{30k + 164k}$$

$$(L): \begin{align*}
4V &- (20k)I_B - (7V) - (2k)I_E = 0 \\
I_B &\rightarrow \ \frac{I_E}{\beta+1} = \frac{I_E}{101} \\
\Rightarrow \quad 4V &- \frac{(20k)I_E}{101} - 7V - (2k)I_E = 0 \\
\Rightarrow \quad 3.3V &\rightarrow (2k)I_E + (198)I_E = 2.198I_E \\
\Rightarrow \quad I_E &\rightarrow \frac{3.3V}{2.198 \times 101} = 1.5mA \\
\Rightarrow \quad I_B &\rightarrow \frac{1.5mA}{101} = 15mA, \quad I_C = \alpha \cdot I_E = (99)(1.5mA) = 1.485mA \\
V_1 = 12V - (4k\Omega)(1.485mA) = 6.06V, \quad V_E = (2k\Omega)(1.5mA) = 3V \\
\Rightarrow \quad V_B = 3.7V
$$
IV. (30 pts) For the circuit shown below,

- Is it a common-emitter, common-base, or common-collector configuration?
- Use the T-model for the transistor and draw the AC (small signal) equivalent circuit of this amplifier network. Neglect the resistance $r_0$.
- Neglect the effect of $r_0$ in the AC equivalent circuit and give the analytical expression of the input resistance $R_{in}$ (looking into the base) as indicated on the diagram below. Remember that the coupling capacitors are assumed to act like shorts at the frequency of the input signal $v_i$. If $\beta = 200$, what is the numerical value of $R_{in}$?
\[ R_{in} = \frac{V_b}{I_b} = \frac{I_c (re + Re)}{V_e} = (\beta+1)(re+Re) \]

\[ \beta = 200 \quad Re = 125 \Omega \]

\[ I_c = 1.2 \text{mA} \quad \text{DC current source} \]

\[ r_e = \frac{25 \text{mV}}{1.2 \text{mA}} = 20.83 \Omega \]

\[ R_{in} = (200+1)(125+125) = 58,250 \Omega \]
I. (25 pts) For the circuits shown below where the diodes are assumed to be ideal, find the values of the labeled currents and voltages.

(a) 
\[
\begin{align*}
+3V & \quad \downarrow \quad I \\
\downarrow & \quad 0V \\
10k\Omega & \\
\downarrow & \quad -3V
\end{align*}
\]

\begin{itemize}
  \item \text{diode vs OFF} \quad \text{\textcolor{red}{+6}}
  \item \text{\textcolor{red}{+3}}
  \item \text{\textcolor{red}{+3}}
  \item \text{\textcolor{red}{+2}}
\end{itemize}

\begin{itemize}
  \item \text{\textcolor{red}{+5}}
  \item \text{\textcolor{red}{+3}}
  \item \text{\textcolor{red}{+5}}
\end{itemize}

(b) 
\[
\begin{align*}
+1V & \quad \downarrow \quad \text{OFF} \\
+3V & \quad \downarrow \quad \text{OFF} \\
2k\Omega & \\
\downarrow & \quad -3V
\end{align*}
\]

\begin{itemize}
  \item \text{\textcolor{red}{+3}}
  \item \text{\textcolor{red}{+5}}
\end{itemize}

\begin{itemize}
  \item \text{\textcolor{red}{+3}}
  \item \text{\textcolor{red}{+2}}
\end{itemize}

I = \frac{3 - (-3)}{2k\Omega} = \boxed{3mA}