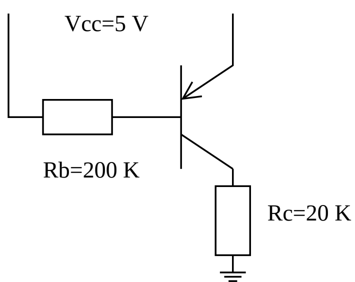
EE 321 Analog Electronics, Fall 2012
Exam 2 October 31, 2012
solution

This is a closed-book exam. Calculators allowed. The exam is designed for conceptual understanding not long derivations. You MUST box your answer. When there are multiples values in an answer summarize them in a single box. Correct answer boxed and derivation gives you 10 points. Either is 5 points. Neither is 0 points.

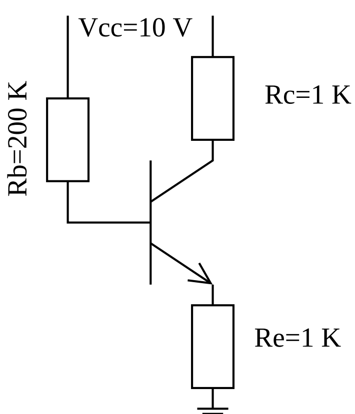
1. **Find all the voltages and currents in this circuit. (Careful!)**



This transistor is in cutoff mode. Thus

$$\boxed{i_C = i_E = i_B = 0 \text{ and } v_B = v_E = 5\,\text{V and } v_C = 0\,\text{V}.}$$

2. **Assuming $\beta = 50$ find all the voltages and currents in this circuit**



Begin with assuming active mode

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

$$i_B = \frac{V_{CC} - V_{BE}}{R_B + (\beta + 1)\, R_E} = \frac{10 - 0.7}{200 + 51 \times 1} = 37.1\,\mu\text{A}$$

$$v_B = V_{CC} - i_B R_B = 10 - 0.2 \times 37.1 = 2.58\,\text{V}$$

$$i_C = \beta i_B = 50 \times 37.1 \times 10^{-3} = 1.86\,\mathrm{mA}$$

$$v_C = V_{CC} - i_C R_C = 10 - 1.86 \times 1 = 8.15\,\mathrm{V}$$

Since $v_C > v_B - 0.4\,\mathrm{V}$ active mode is confirmed.

$$i_E = (\beta + 1)\, i_B = 51 \times 37.1 \times 10^{-3} = 1.89\,\mathrm{mA}$$

$$v_E = i_E R_E = 1.89 \times 1 = 1.89\,\mathrm{V}$$

$\boxed{i_B = 37.1\,\mu\mathrm{A},\ i_C = 1.86\,\mathrm{mA},\ i_E = 1.89\,\mathrm{mA},\ v_B = 2.58\,\mathrm{V},\ v_C = 8.15\,\mathrm{V},\ v_E = 1.89\,\mathrm{V}}$

3. For the same circuit estimate A_{vo} using the quick approximation when it is used as a common-emitter amplifier with emitter resistance (you may assume inputs and outputs are capacitively coupled as in the text book).

$$A_{vo} = -\frac{R_C}{R_E} = -1$$

$\boxed{A_{vo} = -1}$

4. **Design a NPN common-emitter amplifier operating between $V_{CC} = 10\,\text{V}$ supply and ground following these steps in order (again you may assume capacitive coupling of input and outputs for simplicity).**

(a) **What shoule V_C be to get $A_{vo} = -200$?**

$$A_{vo} = -\frac{I_C R_C}{V_T} = -\frac{V_{CC} - V_C}{V_T}$$

$$V_C = V_{CC} + V_T A_{vo} = 10 - 25 \times 10^{-3} \times 200 = 5\,\text{V}$$

$\boxed{V_C = 5\,\text{V}}$

(b) **What is I_C if the output resistance should be $5\,\text{k}\Omega$?**

$R_C = R_{\text{out}}$, and $A_{vo} = -\frac{R_C I_C}{V_T}$, so

$$I_C = -\frac{A_{vo} V_T}{R_C} = \frac{200 \times 25 \times 10^{-3}}{5 \times 10^3} = 1\,\text{mA}$$

$\boxed{I_C = 1\,\text{mA}}$

(c) **If the base is biased with a resistor, R_B, to V_{CC}, what should be the value of R_B? Assume $\beta = 100$.**

$$I_B = \frac{I_C}{\beta} = \frac{1}{100} = 10\,\mu\text{A}$$

$$R_B = \frac{V_{CC} - V_{BE}}{I_B} = \frac{10 - 0.7}{10 \times 10^{-3}} = 930\,\mathrm{k\Omega}$$

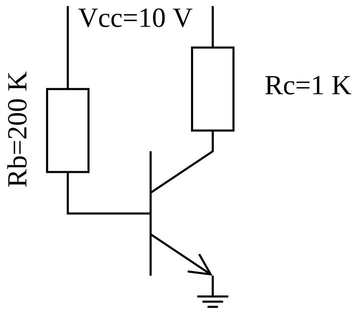
$\boxed{R_B = 930\,\mathrm{k\Omega}}$

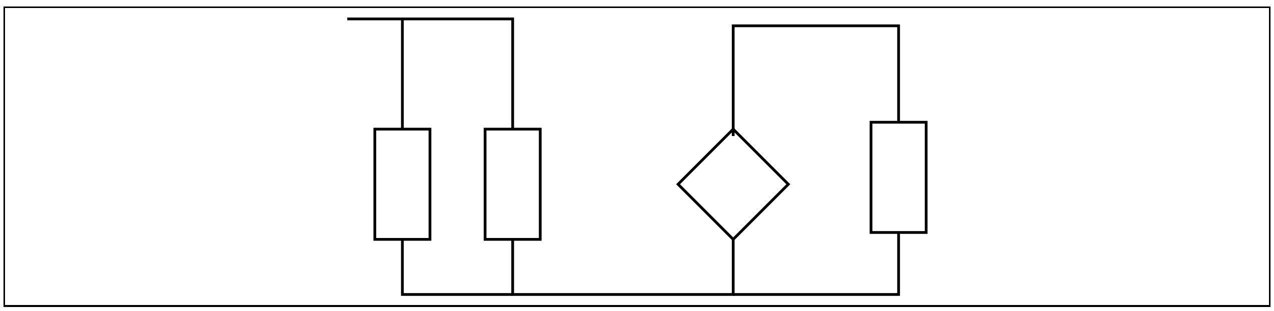
(d) What is the input resistance of this amplifier?

$$R_{\text{in}} = R_B || r_\pi = R_B || \frac{\beta}{g_m} = R_B || \frac{\beta V_T}{I_C}$$
$$= 930 \times 10^3 || \frac{100 \times 25 \times 10^{-3}}{1 \times 10^{-3}}$$
$$= 930 || 2.5 = 2.49\,\mathrm{k\Omega}$$

$\boxed{R_{\text{in}} = 2.49\,\mathrm{k\Omega}}$

5. **Draw the small-signal π-model circuit for this amplifier, give r_π and g_m, R_{in}, and R_{out}, A_{vo}, and G_v if a source has output resistance $R_S = 10\,\text{k}\Omega$ and a $1\,\text{k}\Omega$ load is attached (yet again assume capacitive coupling of inputs and outputs).**





Assume $\beta = 100$, and we get

$$I_B = \frac{V_{CC} - V_{BE}}{R_B} = \frac{10 - 0.7}{200} = 46.5\,\mu\text{A}$$

$$I_c = \beta I_B = 4.65\,\text{mA}$$

$$g_m = \frac{I_C}{V_T} = \frac{4.65}{25} = 0.19\,\Omega^{-1}$$

$$r_\pi = \frac{\beta}{g_m} = \frac{100}{0.19} = 530\,\Omega$$

$$R_{\text{in}} = r_\pi || R_B = r_\pi$$

$$R_{\text{out}} = R_C = 1\,\text{k}\Omega$$

$$A_{vo} = -\frac{I_C R_C}{V_T} = -\frac{4.65 \times 1}{25 \times 10^{-3}} = -186$$

$$
\begin{aligned}
G_v =& \frac{R_{\text{in}}}{R_S + R_{\text{in}}} A_{vo} \frac{R_L}{R_{\text{out}} + R_L} \\
=& -\frac{530}{10 \times 10^3 + 530} \times 186 \times \frac{1}{1+1} \\
=& -4.68
\end{aligned}
$$

$$
\boxed{r_\pi = 538\,\Omega,\ g_m = 0.19\,\Omega^{-1},\ R_{\text{in}} = 530\,\Omega,\ R_{\text{out}} = 1\,\text{k}\Omega,\ A_{vo} = -186,\ G_v = -4.68}
$$