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University of California at Berkeley
Electrical Engineering and Computer Science
EE105 Midterm Examination #1
March 5, 2014
(50 minutes)

CLOSED BOOK; Two standard 8.5" x 11" sheet of notes (both sides) permitted

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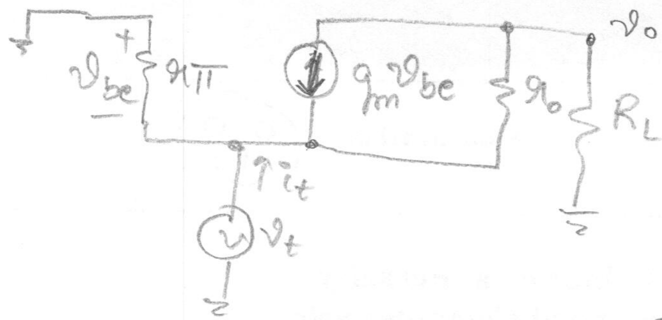
IMPORTANT NOTES

- Read each problem completely and thoroughly before beginning to work on it
- Summarize all your answers in the boxes provided on these exam sheets
- Show your work in the space provided so we can check your work and scan for partial credit
- Remember to put your name in the space above

Problem #	Points Possible	Score
1	20	
2	40	
3	40	
Total	100	

(a)



$$i_t = \frac{v_t}{r_\pi} + g_m v_t$$

$$\frac{v_t - v_o}{r_o}$$

$$\frac{v_o - v_t}{r_o} + \frac{v_o}{R_L} - g_m v_t = 0$$

$$v_o\left(\frac{1}{R_L} + \frac{1}{r_o}\right) = v_t\left(\frac{1}{r_o} + g_m\right)$$

$$v_o = \frac{v_t(1 + g_m r_o)}{(1 + r_o/R_L)}$$

$$i_t = \frac{v_t}{r_\pi} + g_m v_t + \frac{v_t}{r_o} - \frac{v_t}{r_o}\frac{(1 + g_m r_o)}{(1 + r_o/R_L)}$$

$$\frac{i_t}{v_t} = \frac{1}{r_\pi} + g_m + \frac{1}{r_o} - \frac{1}{r_o}\frac{(1 + g_m r_o)}{(1 + r_o/R_L)} \leftarrow$$

$$Z_{in} = \left(\frac{i_t}{v_t}\right)^{-1}$$

(g)

$$\text{Gain} = g_m R_L = \frac{I_c}{V_T} \cdot R_L \Rightarrow \frac{(V_{cc} - V_{CEQ})\cancel{R_L}}{\cancel{R_L} V_T} \Rightarrow \frac{V_{cc} - V_{CEQ}}{V_T}$$

$$\text{If } V_{CEQ} = \frac{V_{cc} + V_{CE,sat}(\approx 0)}{2} = V_{cc}/2$$

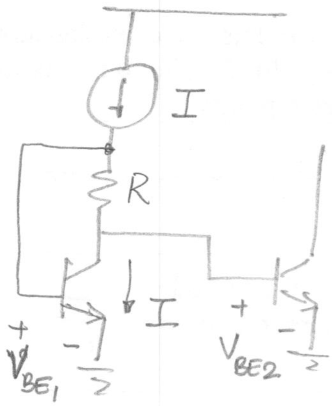
$$\boxed{\text{Gain} = \frac{V_{cc}}{2V_T}}$$

EE105 Spring 2014
D.J. Allstot

1. **True/False questions (20 points)**
For each of the following statements, state "T" for true or "F" for false. No explanation necessary. Correct answers are worth +2 point and incorrect answers yield -2 point. 0 points for unanswered questions. Your minimum total score on this problem is zero points.

(a) The input resistance of a common-base stage depends on the load resistance, R_L. (Include r_o)	T
(b) Assuming a constant current source load, the voltage gain, A_V, of a cascode common-emitter amplifier is twice as large as that of a common-emitter amplifier without cascode.	F
(c) The Early voltage of a BJT can be increased by increasing the doping density in the base region.	T
(d) In an abrupt-junction pn diode, the depletion region is greater on the more lightly doped side.	T
(e) In an abrupt-junction pn diode, the potential drop is greater on the more lightly doped side.	T
(f) In a common-emitter amplifier with a fixed load resistance, R_L, properly biased for maximum signal swing at the output, the voltage gain is doubled as the power supply voltage, V_{CC}, is doubled. Assume $V_{CE}(sat) = 0V$	T
(g) Cascoding can be used to increase the small-signal output resistance of a common-emitter stage.	T
(h) In a common-collector amplifier with an ideal current source connected from the emitter to ground, the small-signal input resistance is r_π.	F
(i) The combination of a degenerated common-emitter amplifier cascaded with a common-collector amplifier is suitable for current amplification.	T
(j) Oski got his/her undergraduate degree at Stanford.	F

2 (a) $\beta_1 = \beta_2 = \infty \Rightarrow$ No base current



$$I = I_s\left(e^{V_{BE_1}/V_T} - 1\right)$$

$$I_o = I_s\left(e^{(V_{BE_1} - IR)/V_T} - 1\right)$$

$$V_{BE_2} = V_{BE_1} - IR$$

Plugging in values $I = 1mA$ $I_s = 10^{-17}$ $R = 100$

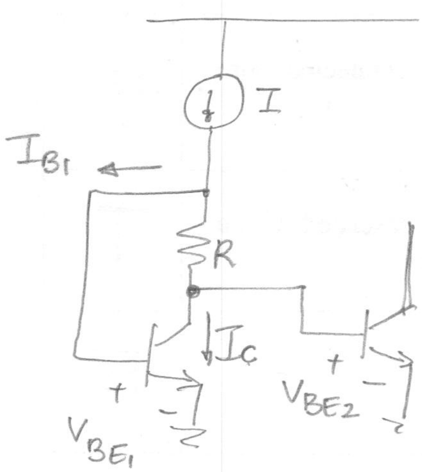
$$V_{BE_1} = V_T \ln\left(\frac{I}{I_s} + 1\right) = 0.8252\text{ V}$$

$$V_{BE_2} = 0.7252\text{V}$$

$$\boxed{I_o = 20.11\,\mu A}$$

2 (b)

when $\beta_1 = 100 \Rightarrow I_{B_1} \neq 0$



$$I_c + I_{B_1} = I$$

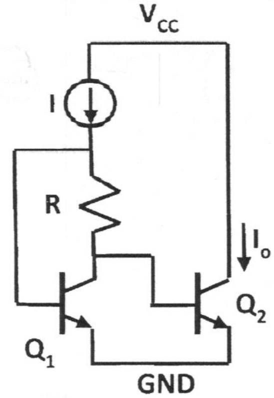
$$I_c = I - I_{B_1} = I - \frac{I_c}{\beta}$$

$$I_c\left(1 + \frac{1}{\beta}\right) = I$$

$$I_c = \frac{I}{(1 + 1/\beta)} = 0.9901\text{ mA}$$

$$V_{BE_1} = V_T \ln\left(\frac{I_c}{I_s} + 1\right) = 0.82499\text{ V}$$

2. DC Bias Circuits (40 points). In the circuit below, all devices operate in the forward-active region (FAR). In all cases, assume $I_{S1} = I_{S2} = 10^{-17}$ A, I = 1 mA and R = 100 Ω.



~~(a) Find the value of I_O with $\beta_1 = \beta_2 = \infty$.~~

$$V_{BE_2} = V_{BE_1} - I_c R$$

$$= 0.82499 - 0.9901 \times 10^{-3} \times 100$$

$$= 0.82499 - 0.09901 = 0.72598 \text{ V}$$

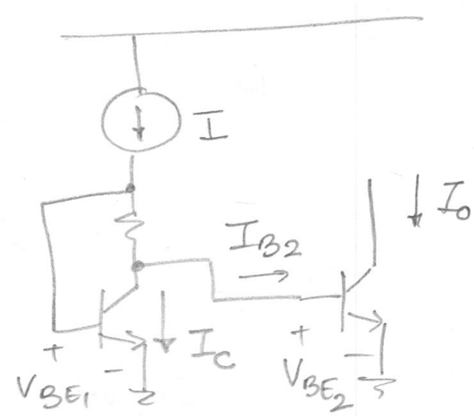
$$I_o = I_S\left(e^{V_{BE_2}/V_T} - 1\right)$$

$$I_o = 20.70\ \mu A$$

2 (c) $\beta_2 = 100 \Rightarrow I_{B2} \neq 0$

$$I = I_{B2} + I_C$$

$$I_{B2} = \frac{I_o}{\beta}$$



(a) I_O =	

$$I = \frac{I_o}{\beta} + I_c \longrightarrow (1)$$

$$I_c = I_s\left(e^{V_{BE1}/V_T} - 1\right) \rightarrow (2)$$

$$V_{BE_1} = V_{BE_2} + IR$$

$$V_{BE_1} = V_T \ln\left(\frac{I_o}{I_s} + 1\right) + IR \longrightarrow (3)$$

From (1), (2) and (3)

$$I - \frac{I_o}{\beta} = I_s\left(e^{IR/V_T} \cdot e^{\ln\left(\frac{I_o}{I_s}+1\right)} - 1\right)$$

$$\Rightarrow I - \frac{I_o}{\beta} = I_s\left[e^{IR/V_T}\left(\frac{I_o}{I_s} + 1\right) - 1\right]$$

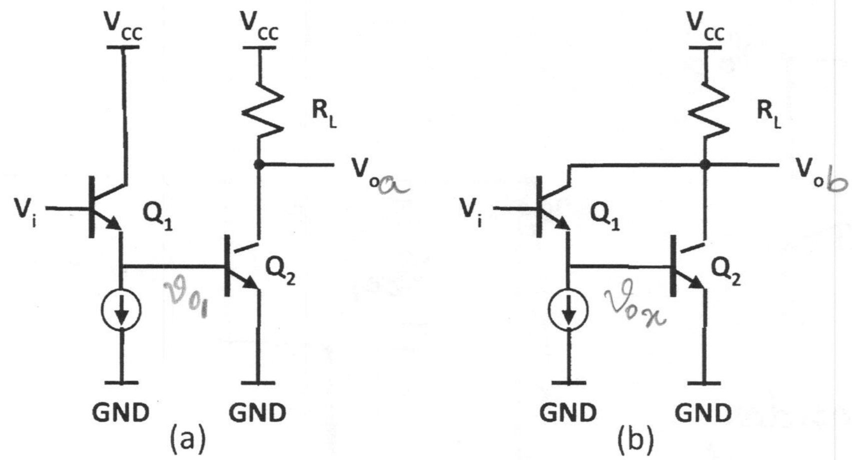
$$I - \frac{I_o}{\beta} = I_o e^{IR/V_T} + I_s e^{IR/V_T} - I_s$$

$$\boxed{\frac{I - I_s e^{IR/V_T} + I_s}{1/\beta + e^{IR/V_T}} = I_o}$$

$I_o = 20.112\ \mu A$

3. (40 points) Small-signal gain calculations. In the circuits below, all devices operate in the forward-active region (FAR). In both cases, assume for DC $V_{BE1} = V_{BE2}$, $\beta_1 = \beta_2 = \infty$ and $V_{A1} = V_{A2} = \infty$.

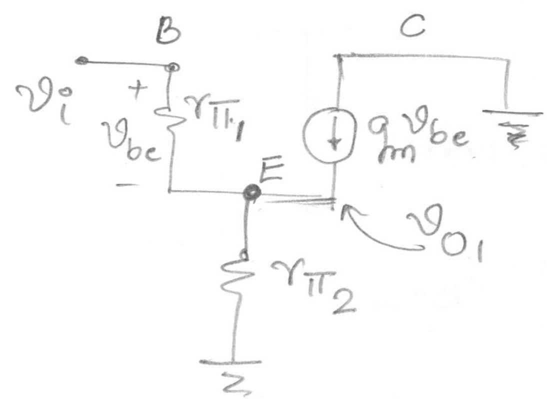
Derive expressions for the small-signal voltage gains, $A_V = V_O/V_i$ and compute the value of the ratio of the two gains, $A_V(b)/A_V(a)$.



For first stage. (a)

$\beta = \infty \; = \; r_\pi \Rightarrow \infty$

(a)



$$\frac{v_{o1} - v_i}{r_{\pi 1}} - g_m (v_i - v_{o1}) + \frac{v_{o1}}{r_{\pi 2}} = 0$$

$$v_{o1}\left(\frac{1}{r_{\pi 1}} + g_m + \frac{1}{r_{\pi 2}}\right) = \left(g_m + \frac{1}{r_{\pi 1}}\right) v_i$$

$$\frac{v_{o1}}{v_i} = \frac{g_m + 1/r_{\pi 1}}{\frac{1}{r_{\pi 1}} + g_m + \frac{1}{r_{\pi 2}}}$$

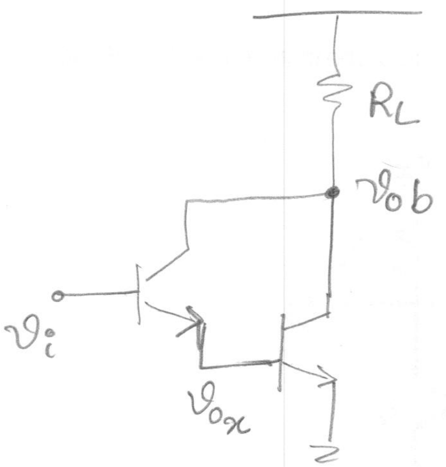
Since $r_{\pi 1}$ and $r_{\pi 2} \to \infty$

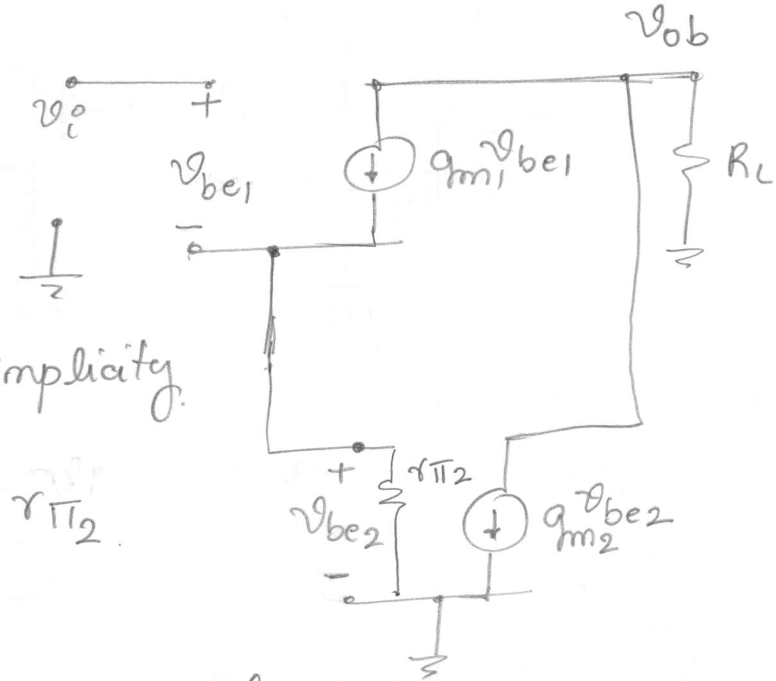
Ava

$$\boxed{\frac{v_{o1}}{v_i} = 1}, \quad \boxed{\frac{v_{oa}}{v_{o1}} = -g_{m2} R_L} \quad \therefore \quad \boxed{\frac{V_{oa}}{v_{o1}} = -g_{m2} R_L}$$

↑ Should be derived

(b) For Case 2





Let us consider only r_{π_2} for simplicity.

$$v_{be_2} = (g_{m_1} v_{be_1}) r_{\pi_2}$$

Since $r_{\pi_2} \to \infty$

$v_{be_1} \to 0$ since v_{be_2} is finite

$$\Rightarrow \quad v_i = v_{be_1} + v_{be_2} \cong v_{be_2}.$$

$$v_{ob} = -v_{be_2} g_{m_2} R_L \quad = -v_i g_{m_2} R_L$$

$$A_{v_b} \quad \boxed{\frac{v_{ob}}{v_i} = -g_m R_L}$$

$$\boxed{\frac{A_{vb}}{A_{vb}} = 1}$$