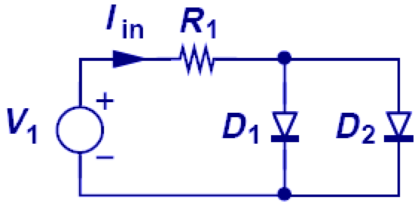
Digital Electronics Spring 2009 Midterm Exam. 04/22/2009

Name: ID#

1. D_1 and D_2 have different cross section areas but are otherwise identical. Determine the current flowing through each diode in terms of I_{in}, I_{S1}, and I_{S2}. (10%)



Ans:

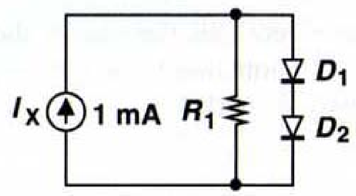
$$I_{in} = I_{D1} + I_{D2}$$

$$V_T \ln \frac{I_{D1}}{I_{S1}} = V_T \ln \frac{I_{D2}}{I_{S2}}$$

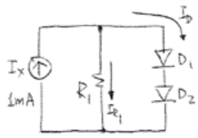
$$\frac{I_{D1}}{I_{S1}} = \frac{I_{D2}}{I_{S2}} \qquad I_{D1} = \frac{I_{D2} I_{S1}}{I_{S2}} \qquad I_{D2} = \frac{I_{D1} I_{S2}}{I_{S1}}$$

$$I_{D1} = \frac{I_{in}}{1 + \frac{I_{S2}}{I_{S1}}} \qquad I_{D2} = \frac{I_{in}}{1 + \frac{I_{S1}}{I_{S2}}}$$

2. In the circuit, determine the value of R_1 such that this resistor carries 0.5 mA. Assume $I_S = 5 \times 10^{-16}$ A for each diode. (10%)



29.



Given $I_{R_1} = 0.5$ mA, $I_S = 5 \cdot 10^{-16}$ A for each diode.

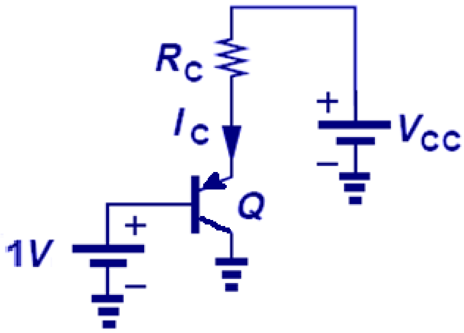
Find R_1.

By KCL, $I_D = I_X - I_{R_1} = 0.5$ mA

$$\Rightarrow V_{D_1} = V_{D_2} = V_T \ln\left(\frac{I_D}{I_S}\right) = 0.026 \ln\left(\frac{0.5\text{mA}}{5 \cdot 10^{-16}\text{A}}\right) \approx 0.718 \text{ V}$$

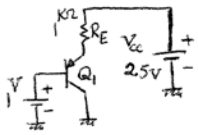
$$\therefore R_1 = \frac{V_{R_1}}{I_{R_1}} = \frac{2V_{D_1}}{I_{R_1}} = \frac{2(0.718\text{V})}{0.5\text{mA}} = 2.87 \text{ k}\Omega$$

3. Calculate the collector current of Q in the following figure? Assume I_S=3×10^{-17}A, R_C=1kΩ, and V_{CC}=2.5V. (10%)



Ans:

(42) $I_S = 3\times10^{-17}$A



Applying KVL,

$$V_{CC} = R_E I_E + V_{EB} + 1^V \xrightarrow{I_E \simeq I_C} V_{CC} = R_E I_C + V_{EB} + 1^V$$

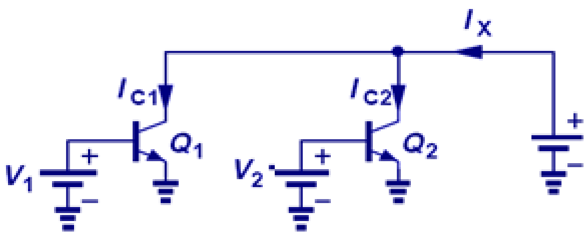
$$\Rightarrow 2.5 = 1^{k\Omega} \times 3\times10^{-17} e^{V_{EB}/26^{mV}} + V_{EB} + 1^V$$

$$\Rightarrow V_{EB} + 3\times10^{-14} e^{V_{EB}/26^{mV}} = 1.5^V$$

$$\Rightarrow \boxed{V_{EB} \simeq 800.5\ mV}$$

$$I_C = I_S e^{\frac{V_{EB}}{V_T}} = 3\times10^{-17} e^{\frac{800.5}{26}} \Rightarrow \boxed{I_C \simeq 0.705\ mA}$$

4. In the following circuit Q_1 and Q_2 are identical and operate in the active mode. Determine $V_1 - V_2$ such that I_{C1} =10I_{C2} (10%)

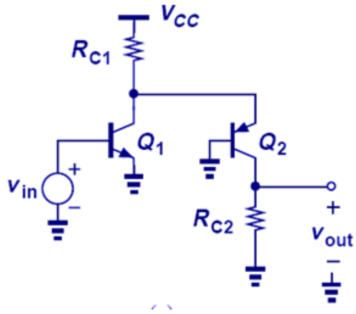


Ans:

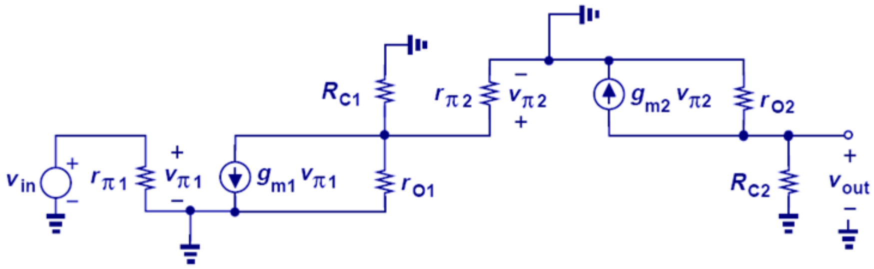
$$\frac{I_{C1}}{I_{C2}} = \frac{I_S \exp\frac{V_1}{V_T}}{I_S \exp\frac{V_2}{V_T}} \qquad \exp\frac{V_1 - V_2}{V_T} = 10$$

$$V_1 - V_2 = V_T \ln 10 \approx 60\text{mV at } T = 300°\text{K}$$

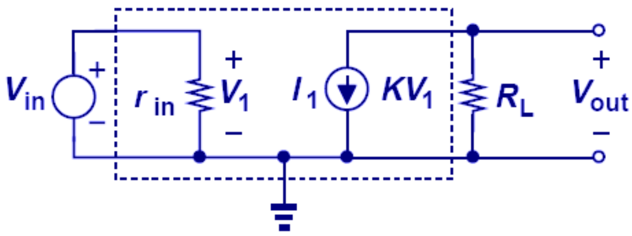
5. Draw the small-signal equivalent circuit for the amplifier shown below. (10%) $V_A \neq \infty$



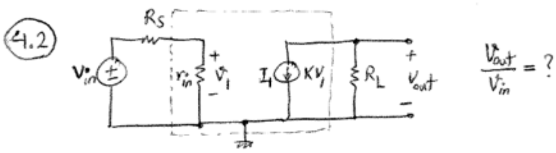
Ans:



6. A resistance of R_S is placed in series with the input voltage source in the following figure. Determine V_{out} / V_{in}. (10%)



Ans:



$\frac{V_{out}}{V_{in}} = ?$

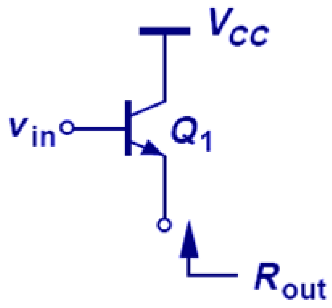
$$V_1 = \frac{r_{in}}{r_{in} + R_S} V_{in}$$

$$\left.\begin{aligned} I_1 &= K V_1 \\ V_{out} &= -R_L I_1 \end{aligned}\right\} \Rightarrow V_{out} = -K R_L V_1$$

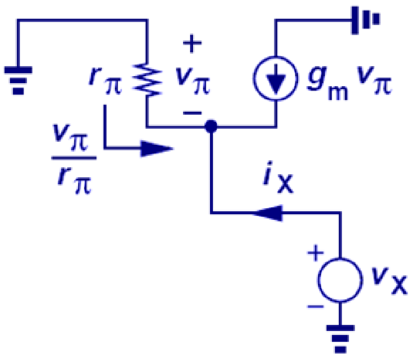
$$\Rightarrow V_{out} = -K R_L \frac{r_{in}}{r_{in} + R_S} V_{in}$$

$$\Rightarrow \boxed{A_v = \frac{V_{out}}{V_{in}} = -K R_L \frac{r_{in}}{r_{in} + R_S}}$$

7. Calculate the impedance seen at the emitter of Q_1 in the following figure. Neglect the Early effect for simplicity. (10%)



Ans:



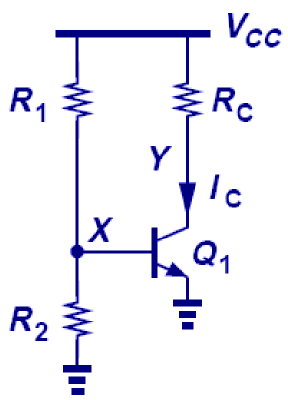
$$g_m v_\pi + \frac{v_\pi}{r_\pi} = -i_x$$

$$\frac{v_x}{i_x} = \frac{1}{g_m + \frac{1}{r_\pi}}$$

$$R_{out} \approx \frac{1}{g_m}$$

$$(V_A = \infty)$$

8. Determine the collector and base current of the following figure if I_S=10^{-17}A and β=100, R_1=31k, R_2=14k ? (10%)



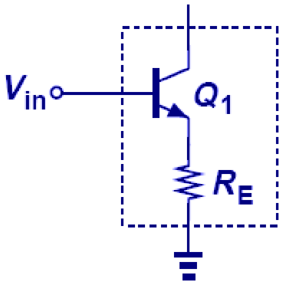
Ans:

$$V_X = \frac{R_2}{R_1 + R_2} V_{CC} = \frac{14k}{31k + 14k} 2.5V = 778mV$$

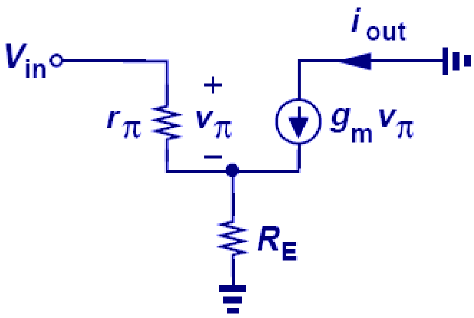
$$I_C = I_S \exp \frac{V_{BE}}{V_T} = 10^{-17} \times \exp \frac{778mV}{26mV} = 98.1uA$$

$$I_B = I_C / \beta = 98.1/100 = 0.981uA$$

9. Please find the G_m of following figure. (10%) where $G_m = \frac{i_{out}}{v_{in}}$, $V_A=\infty$



(a)



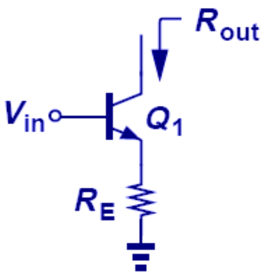
(b)

Ans:

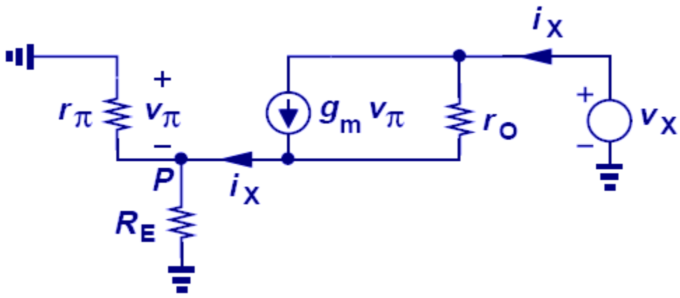
$$V_A = \infty \quad i_{out} = g_m v_\pi \qquad v_{in} = v_\pi + v_{RE} = v_\pi + (\frac{v_\pi}{r_\pi} + g_m v_\pi)R_E = v_\pi[1 + (\frac{1}{r_\pi} + g_m)R_E]$$

$$i_{out} = g_m \frac{v_{in}}{1 + (r_\pi^{-1} + g_m)R_E} \qquad G_m = \frac{i_{out}}{v_{in}} \approx \frac{g_m}{1 + g_m R_E}$$

10. Please find the R_{out} of following figure. (10%) $V_A \neq \infty$



(a)



(b)

Ans:

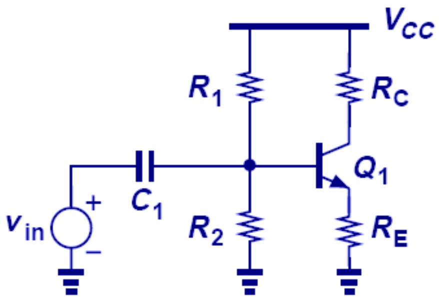
$$v_\pi = -i_x(R_E \parallel r_\pi) \quad v_x = (i_x - g_m v_\pi)r_o - v_\pi$$

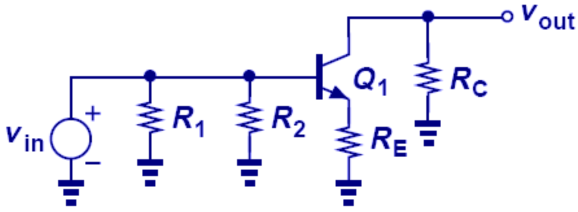
$$v_x = [i_x + g_m i_x(R_E \parallel r_\pi)]r_o + i_x(R_E \parallel r_\pi)$$

$$R_{out} = [1 + g_m(R_E \parallel r_\pi)]r_O + R_E \parallel r_\pi \qquad R_{out} = r_O + (g_m r_O + 1)(R_E \parallel r_\pi)$$

$$R_{out} \approx r_O[1 + g_m(R_E \parallel r_\pi)]$$

11. Please find the R_{in} of following figure. (5%) $V_A=\infty$





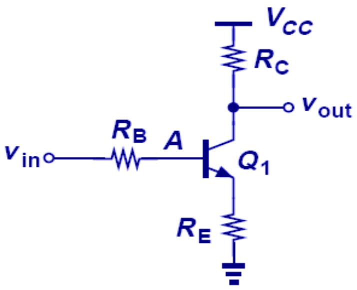
Ans:

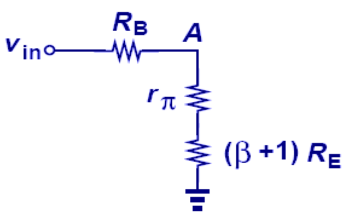
$$v_X = r_\pi i_X + R_E(1+\beta)i_X$$

$$R_{inQ1} = \frac{v_X}{i_X} = r_\pi + (\beta+1)R_E$$

$$R_{in} = \left[r_\pi + (\beta+1)R_E\right] \| R_1 \| R_2$$

12. Please find the gain of following figure. (Degenerated CE Stage with Base Resistance) (15%) $V_A=\infty$





Ans:

$$V_A = \infty \qquad \frac{v_A}{v_{in}} = \frac{r_\pi + (\beta+1)R_E}{r_\pi + (\beta+1)R_E + R_B} \qquad \frac{v_{out}}{v_A} = \frac{-g_m R_C}{1+(\frac{1}{r_\pi}+g_m)R_E}$$

$$\frac{v_{out}}{v_{in}} = \frac{v_A}{v_{in}} \cdot \frac{v_{out}}{v_A} = \frac{r_\pi + (\beta+1)R_E}{r_\pi + (\beta+1)R_E + R_B} \cdot \frac{-g_m R_C}{1+(\frac{1}{r_\pi}+g_m)R_E}$$

$$= \frac{r_\pi + (\beta+1)R_E}{r_\pi + (\beta+1)R_E + R_B} \cdot \frac{-g_m r_\pi R_C}{r_\pi + (1+\beta)R_E} = \frac{-\beta R_C}{r_\pi + (\beta+1)R_E + R_B}$$

$$A_v \approx \frac{-R_C}{\frac{1}{g_m} + R_E + \frac{R_B}{\beta+1}}$$