Digital Electronics Spring 2011 Midterm Exam 04/27/2010

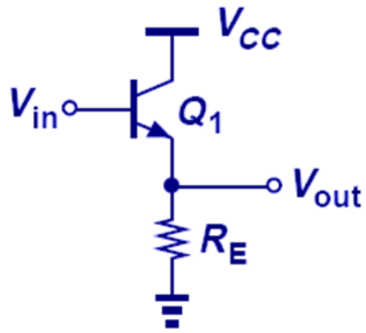
Name: ID#

1. A 3-V adaptor using a half-wave rectifier must supply a current of 0.5A with a maximum ripple of 300mV. For a frequency of 60 Hz, computer the minimum required smoothing capacitor. The relation of the load current, capactitor, frequency, ripple is $V_R = I_L/(C_1 f_{in})$ (8%)

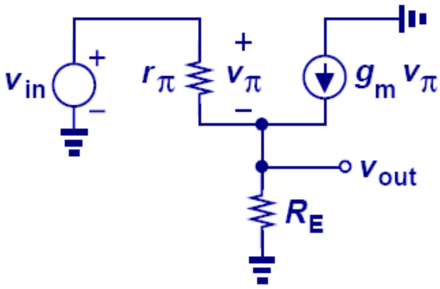
Ans:

$$V_R = \frac{I_L}{C_1 f_{in}} \leq 300\ \text{mV}$$
$$f_{in} = 60\ \text{Hz}$$
$$I_L = 0.5\ \text{A}$$
$$C_1 \geq \frac{I_L}{(300\ \text{mV})\, f_{in}} = \boxed{27.78\ \text{mF}}$$

2. Draw the small-signal equivalent circuit for the amplifier shown below, neglecting r_O. (8%)



Ans:



3. A transistor with $I_S = 6\times10^{-16}$A must provide a transconductance of (1/13)Ω. What is base-emitter voltage is required? (8%)

Ans:

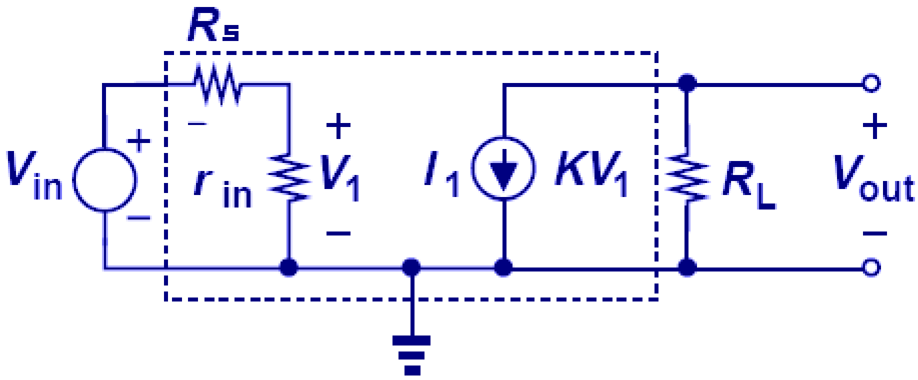
(19) $g_m = \frac{I_C}{V_T}$

$$\Rightarrow g_m = \frac{I_S \exp\left(\frac{V_{BE}}{V_T}\right)}{V_T} \Rightarrow \boxed{V_{BE} = V_T \ln\left(\frac{g_m V_T}{I_S}\right)}$$

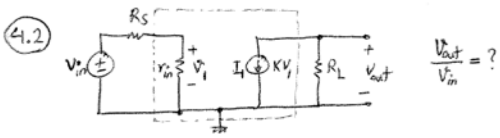
$I_S = 6\times10^{-16}$ A, $g_m = \frac{1}{13\Omega}$ $\rightarrow$ $V_{BE} = 26^{mV} \cdot \ln\left(\frac{\frac{1}{13\Omega}\times 26\times10^{-3}}{6\times10^{-16}}\right)$

$$\Rightarrow \boxed{V_{BE} \simeq 750\ mV}$$

4. Determine V_{out} / V_{in}. (8%)



Ans:

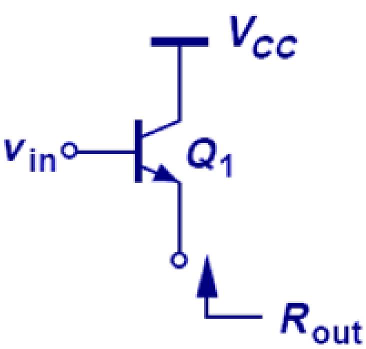


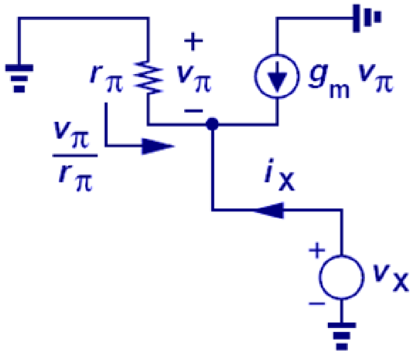
$$V_1 = \frac{r_{in}}{r_{in}+R_S} V_{in}$$

$$\left.\begin{array}{l} I_1 = K V_1 \\ V_{out} = -R_L I_1 \end{array}\right\} \Rightarrow V_{out} = -K R_L V_1 \quad \Rightarrow V_{out} = -K R_L \frac{r_{in}}{r_{in}+R_S} V_{in}$$

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

5. Calculate the impedance seen at the emitter of Q_1 in the following figure. Neglect the Early effect for simplicity. (8%)



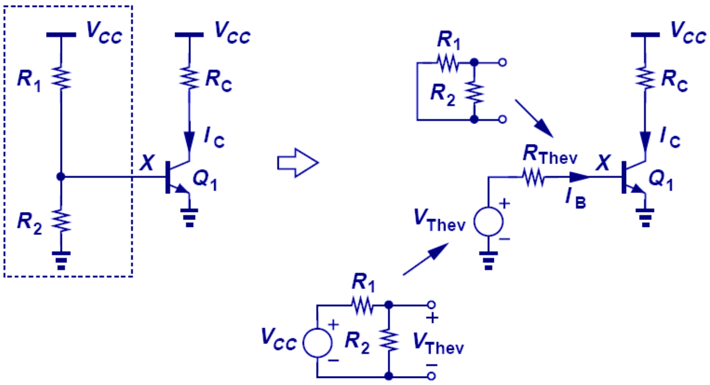


Ans:

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

$$\frac{v_x}{i_x} = \frac{1}{g_m + \frac{1}{r_\pi}} \qquad R_{out} \approx \frac{1}{g_m} \qquad (V_A = \infty)$$

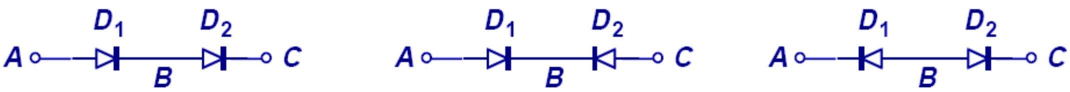
6. Determine the V_{Thev} and R_{Thev} of the following figure? (8%) R_1=170KΩ, R_2=80 KΩ, R_C=5 KΩ,V_{CC}=2.5V



Ans:

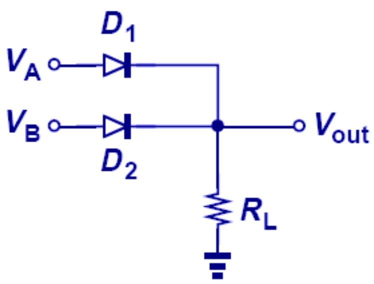
$$V_{Thev} = \frac{R_2}{R_1 + R_2} V_{CC} = \frac{80k}{170k + 80k} 2.5 = 800\text{mV}$$
$$R_{Thev} = R_1 \| R_2 = 170\text{k} \| 80k = 54.4k$$

7. 1 (a) Which one of the following figure can conduct current from A to C (2%)

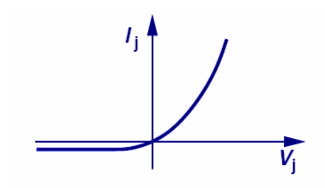


(a) (b) (c)

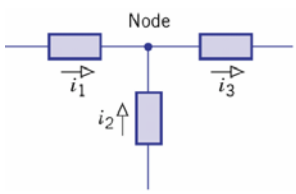
7.2 (c) What function does the following figure perform? (a) NOT (b) AND (c) OR gate (2%)



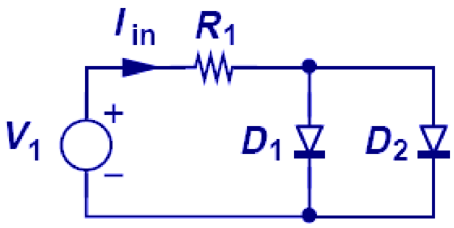
7.3 (b) What is the diode model of the following figure ? (a) Constant voltage model (b) Exponential model (c) Ideal model (2%)



7.4. (c) What is the current equation in the following figure ? (a) $i_1= i_2+ i_3$ (b) $i_2= i_1+ i_2$ (c) $i_3= i_1+ i_2$ (2%)



8. D_1 and D_2 have different cross section areas but are otherwise identical. Determine the current flowing through each diode. (8%)



Ans:

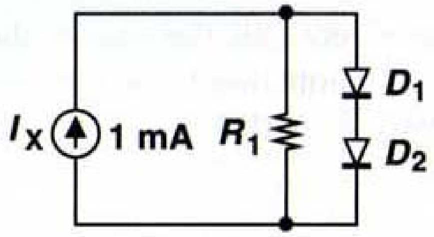
$$I_{in} = I_{D1} + I_{D2}$$

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

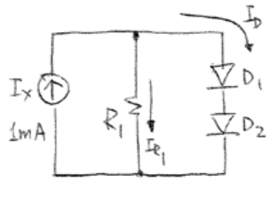
$$\frac{I_{D1}}{I_{S1}} = \frac{I_{D2}}{I_{S2}}$$

$$I_{D1} = \frac{I_{in}}{1+\dfrac{I_{s2}}{I_{s1}}} \qquad I_{D2} = \frac{I_{in}}{1+\dfrac{I_{s1}}{I_{s2}}}$$

9. In the circuit, determine the value of R_1 such that this resistor carries 0.5 mA. Assume $I_S = 5\times10^{-16}$ A for each diode. (8%)



29.



Given $I_{R_1} = 0.5$ mA, $I_S = 5\cdot10^{-16}$ A for each diode.

Find R_1.

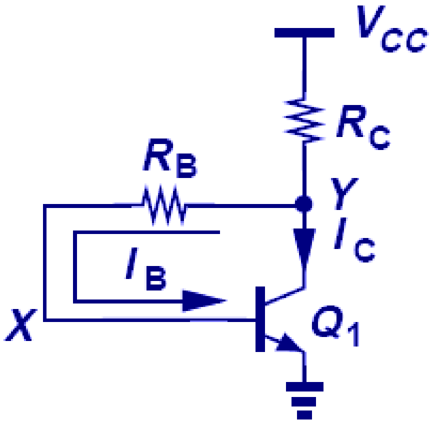
By KCL, $I_D = I_X - I_{R_1} = 0.5\,mA$

$\Rightarrow V_{D_1} = V_{D_2} = V_T \ln\left(\frac{I_D}{I_S}\right) = 0.026 \ln\left(\frac{0.5mA}{5\cdot10^{-16}A}\right)$

$\approx 0.718\ V$

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

10. For the self-biasing circuit, please find the current I_C respect to the V_{CC}, V_{BE}, R_C, R_B , and β. (10%)



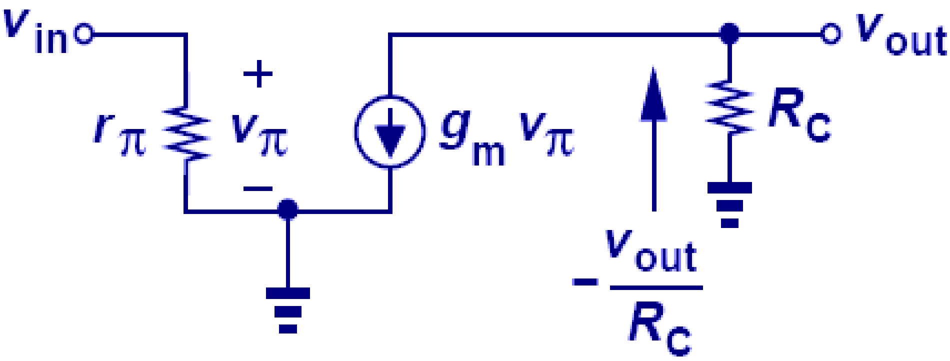
Ans:

$$V_Y = V_{CC} - R_C I_C$$

$$V_Y = R_B I_B + V_{BE} = \frac{R_B I_C}{\beta} + V_{BE}$$

$$I_C = \frac{V_{CC} - V_{BE}}{R_C + \frac{R_B}{\beta}}$$

11. Please find the voltage gain of the common emitter configuration. (8%) $A_v = V_{out} / V_{in}$



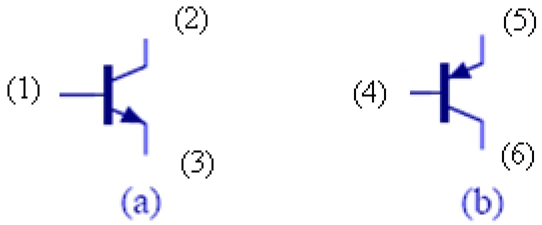
Ans:

$$A_v = \frac{v_{out}}{v_{in}}$$

$$-\frac{v_{out}}{R_C} = g_m v_\pi = g_m v_{in}$$

$$A_v = -g_m R_C$$

12. Please use the following figure to answer the questions. (8%)



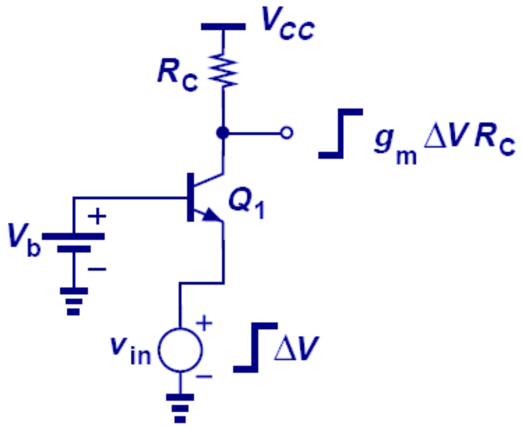
12.1 (b) Which of these two figures is PNP transistor. (please determine a or b)?

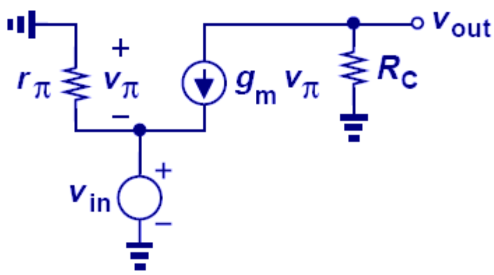
12.2 (1, 4) Which labels (1, 2, 3, 4, 5, or 6) of these two figures are the base terminals?

12.3 (2, 6) Which labels (1, 2, 3, 4, 5, or 6) of these two figures are the collector terminals?

12.4 (3, 5) Which labels (1, 2, 3, 4, 5, or 6) of these two figures are the emitter terminals?

13. Please find the voltage gain of the common base configuration. (8%) $A_v = V_{out} / V_{in}$

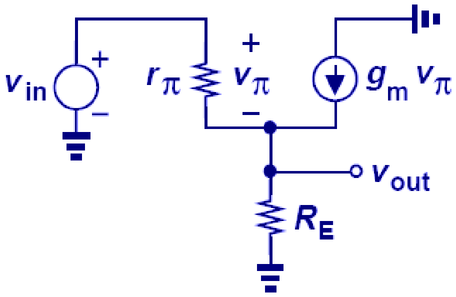




$$-\frac{v_{out}}{R_C} = g_m v_\pi \qquad v_\pi = -v_{out} / (g_m R_C)$$

$$\frac{v_{out}}{v_{in}} = g_m R_C \qquad A_v = g_m R_C$$

14. Please find the voltage gain of the common collector configuration. (8%) $A_v = V_{out} / V_{in}$



Ans:

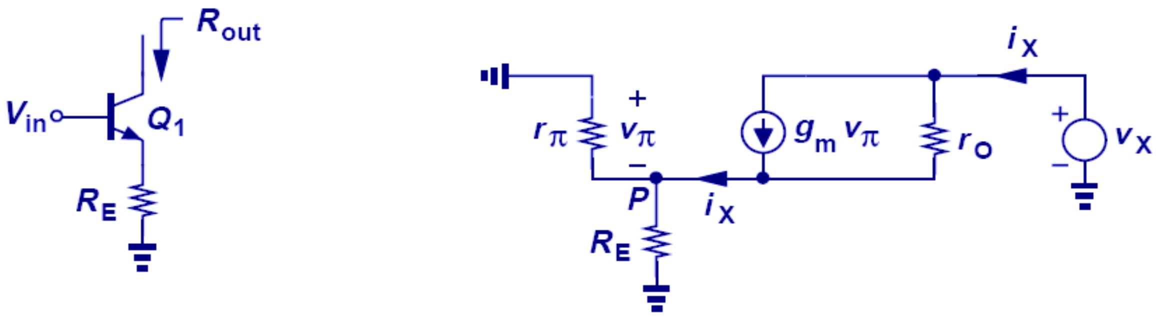
$$V_A = \infty$$

$$\frac{v_\pi}{r_\pi} + g_m v_\pi = \frac{v_{out}}{R_E} \Rightarrow v_\pi = \frac{r_\pi}{\beta + 1} \cdot \frac{v_{out}}{R_E}$$

$$v_{in} = v_\pi + v_{out}$$

$$\frac{v_{out}}{v_{in}} = \frac{1}{1 + \frac{r_\pi}{\beta + 1} \cdot \frac{1}{R_E}} \quad or \quad \frac{v_{out}}{v_{in}} = \frac{1}{1 + \frac{r_\pi}{g_m r_\pi + 1} \cdot \frac{1}{R_E}}$$

15. Please find the output impedance of the following figure. (8%)



(a) (b)

Ans:

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

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

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

$$or$$

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