(A) Please answer the following questions briefly

1. Please explain the Early effect in both BJT and MOSFET with device cross-section. (8%)
2. Please briefly draw the band diagram of both BJT and MOSFET. In addition, please also draw the band diagram of BJT in active operation region and MOSFET in saturation operation region. (8%)
3. Please draw the minority-carrier distribution of a pn junction in both forward-bias and reverse-bias region. At the same time, please also use diagrams to explain capacitances seen in a pn junction. (8%)
4. Please explain the breakdown behaviors of a diode. And also explain how temperature affects the behavior of a diode. (6%)

(B) Please calculate the following questions.

1. For the amplifier circuit shown in Figure 1, the NMOS transistor has the following parameters: $W/L = 0.9\mu m/0.18\mu m$, $\mu_n C_{ox} = 1600\ \mu A/V^2$, threshold voltage $V_{TN} = 0.5$ V, and $V_A = 10$ V. Both capacitors are coupling capacitors.
   (1) Calculate the DC operation point of the amplifier (find V_G, V_D, and I_D). (9%)
   (2) Find the amplifier gain (V_{out}/V_{in}). (5%)
   (3) If the resistor R_G is changed to 10 kΩ, how does this affect the DC operating point? What is the amplifier gain (V_{out}/V_{in}) now? (8%)

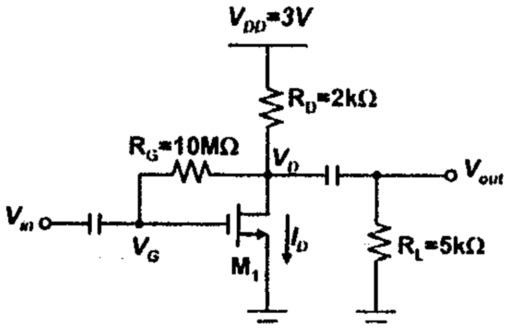

Figure 1

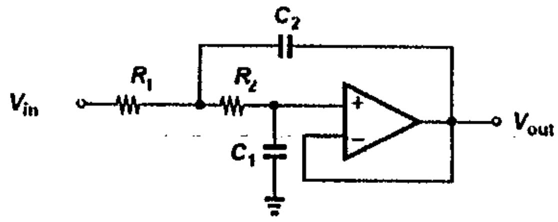

Figure 2

2. An op amp-based filter is shown as Figure 2. The maximum/minimum output of the op amp are 5V/0V, respectively. Assume $V_{out}(t=0)=0$.
   (1) Assume the gain and the bandwidth of the op amp are infinite. Derive $H(\omega)= V_{out}(\omega)/V_{in}(\omega)$ (6%)
   (2) Based on the answer in (a), what is $|H(\omega=0)|$ and $|H(\omega=\infty)|$. (6%)
   (3) Repeat part (a) if the gain of the op amp is finite and is equal to A_v. (8%)
   (4) Assume $V_{in}(t)=6*\sin(2\pi(10\ Hz)t)$ and sketch $V_{out}(t)$ as a function of time. Note that $R_1= R_2$=1K and $C_1= C_1= C_2$=1nF. (5%)
3. As shown in Figure 3. The transistor parameters are V_{TN1}=0.6V, V_{TP2}=-0.6V, K_{n1}=0.2mA/V^2, K_{p2}=1.0mA/V^2, and $\lambda_1=\lambda_2=0$. In addition, V_{DD}=5V, and R_{in}=400kΩ.
   (1) Design the circuit such that I_{D1}=0.2mA, I_{D2}=0.5mA, V_{DS1}=2V, and V_{SD2}=3V. (9%)
   (2) Draw the small-signal model of this multi-stage amplifier. (8%)
   (3) Determine the small-signal voltage gain $A_v=v_O/v_i$. (6%)

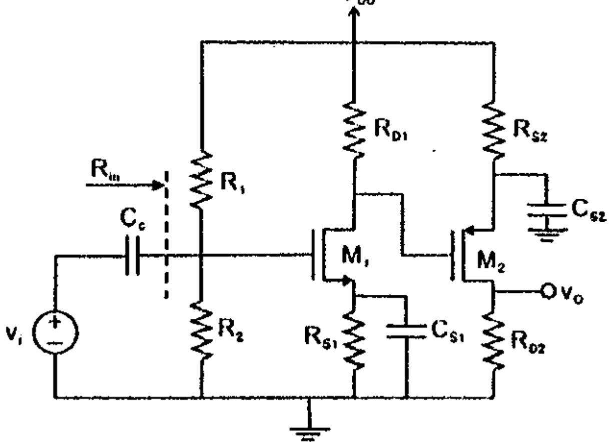

Figure 3.

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