1. In Fig. 1, Q_1 has $\beta = 100$, $V_A = 13$ V, and is biased at $V_{BE} = 0.7$V, $I_C = 1$ mA. Also $V_T = 26$ mV. $V_{CC} = 3$V, $V_b = 1$V.
   (a) Calculate the DC voltages at V_{in} and V_{out} nodes. (4 points)
   (b) Calculate the voltage gain (A_v), input resistance (R_{in}), and output resistance (R_{out}). (6 points)

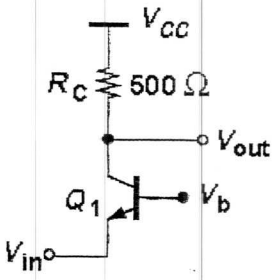

Fig. 1

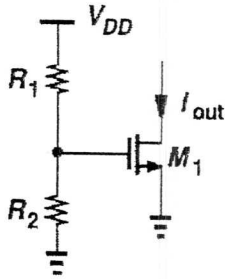

Fig. 2

2. In Fig. 2, assume M_1 is biased at saturation and has $(W/L)_1 = 100$, $\mu_n C_{ox} = 100\mu A/V^2$, $V_{TH} = 0.8$V, $\lambda = \gamma = 0$. $V_{DD} = 3$V, $I_{out} = 200\mu A$.
   (a) Find V_{GS} of M_1. (5 points)
   (b) Determine R_1/R_2. (5 points)

3. In Fig. 3, find V_{GS} and I_D of M_1. $\mu_n C_{ox} = 100\ \mu A/V^2$, $V_{TH} = 0.5$ V, $\lambda = 0$. (10 points)

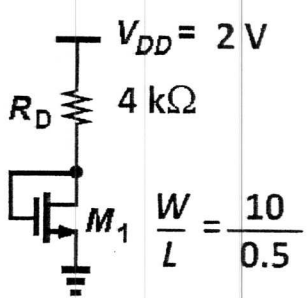

Fig. 3

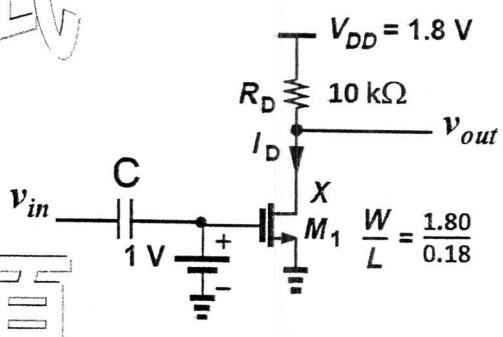

Fig. 4

4. For the circuit shown in Fig. 4, M_1 has $\mu_n C_{ox} = 80\ \mu A/V^2$, $V_{TH} = 0.5$ V, $\lambda = 0.1V^{-1}$.
   (a) Find the current (I_D), transconductance (g_m) and ouput resistance (r_O) of M_1. (6 points)
   (b) If C is large enough, find the voltage gain A_v ($= v_{in}/v_{out}$). (4 points)
   (c) What is tha maximum value of R_D such that M_1 stays at saturation? (5 points)

5. In Fig. 5, the MOSFETs have their geometry size as labelled, and V_{DD} is 5V. Calculate the voltage values of V_1 and V_2. (5 points)

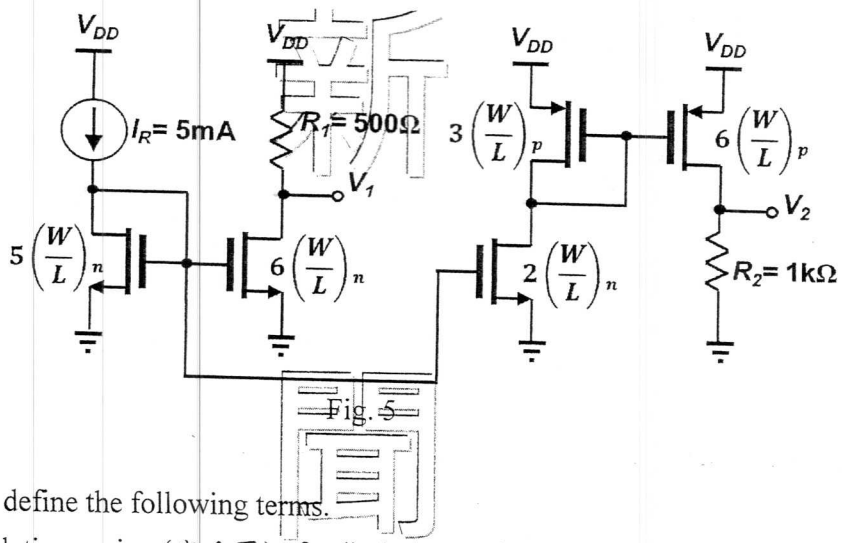

Fig. 5

6. Please define the following terms.

(a) Depletion region (空乏區) of a diode (二極體) (5 points)

(b) Junction capacitance (接面電容) of a diode (5 points)

(c) Drift current (飄移電流) (5 points)

(d) Diffusion current (擴散電流) (5 points)

(e) N-type doping (N-型摻質) (5 points)

7. Fig. 6 shows the small-signal model including channel-length modulation of a MOSFET. Prove output resistance r_o and transconductance g_m can be represented as follows:

(a) $r_O \approx \dfrac{1}{\lambda I_D}$ (5 points)

(b) $g_m = \mu_n C_{ox} \dfrac{W}{L}(V_{GS} - V_{TH})$ (5 points)

(c) $g_m = \sqrt{2\mu_n C_{ox} \dfrac{W}{L} I_D}$ (5 points)

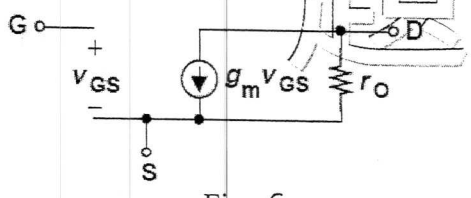

Fig. 6

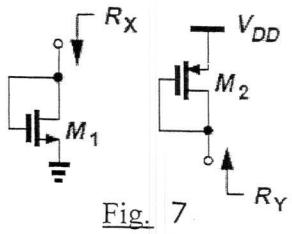

Fig. 7

8. For the configurations shown in Fig. 7 determine the small-signal resistances R_X and R_Y. Assume $\lambda \neq 0$. (10 points)