(1) Operation amplifier (OP AMP) as shown in Fig. 1.

(a) What are the conditions for ideal OP AMP  

(b) Find \( A_v = \frac{v_o}{(v_1 - v_2)} \) for the circuit bellow.(All OP AMPs are ideal)  

![Fig. 1](image)

(2) In the circuit shown as Fig. 2, assume the circuit parameters be:  
\( R_1 = 5\,\text{k}\Omega, \quad R_2 = 10\,\text{k}\Omega, \quad V^+ = 5V, \quad V^- = -5V \), the diode turn-on voltage \( V_r = 0.7V \)

(a) Determine \( v_o, i_{D1}, i_{D2} \) for \( v_i = 0V \)  

(b) Determine \( v_o, i_{D1}, i_{D2} \) for \( v_i = 4V \)  

![Fig. 2](image)
(3) Find the voltage gain of the following circuit with the switch in position 1, 2, and 3. The circuit is shown in Fig. 3 (15 分)

![Circuit Diagram](image)

**Fig. 3**

(4) The circuit is shown in Fig. 4

(a) Find the \( A_v(s) = \frac{V_o(s)}{V_i(s)} \) (5 分)

(b) What is the type of this filter? (5 分)

![Circuit Diagram](image)

**Fig. 4**

(5) The circuit is shown in Fig. 5
The \( \beta \) of BJT Q is 100. And the capacitances and resistances are as following:
\[ C_B = C_C = 1 \mu F \\
R_1 = 3.3 k \Omega \\
R_2 = 1 k \Omega \\
R_3 = 100 k \Omega \\
R_4 = 47 k \Omega \]

A. Calculate the DC collector current \( I_C \) (5 分)

B. If we have an input of \( v_i(t) = 10 \cos(2\pi 10^5 t) \) mV, where \( t \) is in unit of second. What is \( v_o(t) \)? (5 分)

![Fig. 5](attachment:image.png)

(6)

Shown in the figure 6 is a matched CMOS inverter with its loading capacitance.

A. Draw qualitatively the static \( i-v \) curve of the two MOS (i.e. the drain current versus output voltage when input is low and output is high, and explain its static voltage transfer characteristic \( v_o \) versus \( v_i \) with \( v_i \) changing from zero to maximum. Use both texts and figures.(5 分)

B. Mark out the break points with values specified. Explain the transistor operation in different regions. (5 分)

C. Then graphically explain the dynamic operation as input suddenly goes high. (5 分)
Fig. 6. CMOS Inverter

(7)
An inverter circuit is shown in Fig. 7(a). The output current-voltage characteristics of transistors Q₁ and Q₂, and the transfer characteristics of this inverter are shown in Fig. 7(b), 7(c), and 7(d), respectively. Assume that $C_L=0.3 \text{ pF}$ and the input signal has $V(0)=0.3\text{V}$ and $V(1)=6\text{V}$. Please determine the values of the propagation delay $t_{\text{PHL}}$ and $t_{\text{PLH}}$. (15 分)
(8)

High-frequency model: the following Fig. 8 shows the high frequency model of a BJT in common-emitter. We define the $h_{fe}$ as the forward common-emitter high frequency gain, and it follows: $h_{fe} \equiv I_c/I_b$ (in Fig. 8).

A. Using s-domain analysis or frequency domain analysis, find out what $h_{fe}$ is in terms of $s$ (or $j\omega$), $g_m$, $V_\pi$, $C_\pi$, $C_\mu$, $r_\pi$, $r_x$, and $r_o$? (Note: not all parameters are needed.) (5 分)

B. If the transconductance $g_m$ is dominating over this high frequency circuit, (meaning $g_m >> \omega C_\pi$, or $\omega C_\mu$), what is the 3dB-frequency $\omega_B$?

What is the cut-off frequency $\omega_T$? (5 分)

C. Sketch the Bode plot for $|h_{fe}|$, mark the $\omega_T$ (cut-off frequency), and $\omega_B$. (5 分)