For NMOS transistors assume \( k = 4 \text{mA/V}^2 = \frac{(Kp)}{2}(W/L) \), \( V_{TO} = 1 \text{V} \), \( \lambda = 0 \); for PMOS assume complementary to NMOS except \( k = 2 \text{mA/V}^2 \).

For bipolar assume \( \beta = 100 \), \( V_A = \text{Early voltage} = 200 \text{V} \)

1. (20 points 10 minutes; NMOS inverter)
   For the following circuit determine the input voltage \( V_{tr} \) for which when \( v_{in} > V_{tr} \) the NMOS transistor is in the triode region.

   ![NMOS Inverter Circuit](image)

2. (35 points, 20 min; NMOS bias & gain)
   For the following NMOS amplifier assume \( RL = RS = 2k \Omega \) and \( RA \) need not = \( RB \) (and not necessarily large).
   a) For \( I_D = 1 \text{mA} \) find the Q point (bias) values for \( V_{GS} \) and \( V_{DS} \) and check that the transistor is in saturation
   b) Draw the mid-band gain small signal equivalent circuit and give the mid-band voltage gain \( A_v = \frac{v_{out}}{v_{in}} \) (where voltages are measured with respect to ground and the capacitors are assumed shorts) [include \( RA \) & \( RB \)].

   ![NMOS Amplifier Circuit](image)
3. (25 points, 20 min; OTA circuit gain and ODE)

![OTA Circuit Diagram]

a) For this circuit give the voltage transfer function $A_v(s)$.

b) Give the differential equation relating $v_o(t)$ to $v_i(t)$.

4. (20 points 10 minutes; Small signal parameters)

The FIN-FET is a new transistor being considered for quantum systems. An N-type FIN-FET with $n$ fins has the same circuit symbol and is like an NMOS (with no gate current and bulk tied to source) but has the $n$-power law ($n=$number of fins, any positive real $n$ but normally an integer)

Off: $i_D=0$ for $v_{GS}<V_{th}$

And for $v_{GS}\geq V_{th}$:

Saturation: $i_D=k(v_{GS}-V_{th})^n(1+\lambda v_{DS})$ for $v_{DS}\geq(v_{GS}-V_{th})$

Triode: $i_D=k([2(v_{gs}-V_{th})^{n/2}/v_{DS}^{n/2})]-v_{DS}^{n}(1+\lambda v_{DS})$ for $v_{DS}\leq(v_{GS}-V_{th})$

a) Show that there is a number of fins, $n$, for which the FIN-FET behaves like an NMOS transistor

b) For any positive real $n$, assuming a FIN-FET is biased to be in saturation, find its $g_m$ and $g_{o}$ in terms of Q point values and draw low frequency equivalent circuit.