INSTRUCTIONS:

1. **THIS EXAM IS CLOSED BOOK AND CLOSED NOTES** other than one-side of a 3”x5” note card.

2. **YOU MAY USE ONE OF THESE CALCULATORS.**
   - Casio fx-115/fx-991
   - HP 33s/35s
   - TI 30X/36X

3. Work each problem in the provided space OR on blank paper pages.

4. Show ALL work required to arrive at a solution for either full or partial credit.

5. READ the entire question before answering.

6. **SUBMIT ALL OF YOUR WORK TO THE FINAL EXAM ELEARNING DROPBOX BY TODAY AT 12:25PM IN PDF FORMAT.**

7. SIGN the honesty pledge at the bottom of the page. Exams without a signature will receive no credit.

I have neither given nor received assistance from anyone in regards to completion of this exam.  
I have followed the instructions as provided on this sheet.  
I have verified that the exam has (11) pages.

SIGNATURE: ___________________________ DATE: ____________

Note: some problems might be adapted from the course text or other sources.  
Schematics prepared using LTspice® (linear.com). © 2021 Damon A. Miller
Maximum exam score is 45/45.

1. (3 pts) Using a graph, illustrate why the transconductance of an NMOS transistor is positive.

2. (2 pts) What is the most difficult value of closed-loop gain to stabilize?
3. Consider the following circuit. The op-amp is ideal.

![Circuit Diagram]

a. (4 pts) Find $r_i$, $A_v$, and $r_o$ for this small signal model of the amplifier:

![Small Signal Model Diagram]

b. (2 pts) If the amplifier is driven by a voltage source $v_s$ with a 1k output resistance and a load resistance of 1k is connected to the amplifier output terminals, find the effective voltage gain $v_o/v_s$.

c. (2 pts) Find the short-circuit amplifier current gain (current through a shorted output vs current through $r_i$).

d. (2 pts) What value of load resistance dissipates maximum power?
EXTRA WORK SPACE FOR PROBLEM 3
4. Consider the following circuit. Ignore $\lambda$. $k_n=2\text{ mA/V}^2$ includes $W/L$.

![Circuit Diagram](image)

Adapted directly from: Sedra and Smith, Microelectronic Circuits, 3rd ed.

a. (2 points) Find the Q point ($I_D$, $V_{DS}$).
b. (2 points) Verify that the transistor is in the saturation region.
c. (4 points) Draw the small-signal equivalent circuit diagram.
d. (2 points) Use (c) to find the small signal voltage gain $v_o/v_i$. 
5. An operational amplifier has the following open-loop gain and phase characteristics. Note that the poles are at 100Hz, 10kHz, and 1MHz.
   a. (2 points) Find the minimum stable closed-loop gain.
   b. (2 points) For a closed-loop gain of 80dB find the phase margin.
   c. (2 points) For a closed-loop gain of 40dB find the gain margin.
   d. (4 points) Find a new frequency for the first pole so that the operational amplifier can be used in a unity feedback circuit with a phase margin of at least 45º.
(GRAPH REPEATED)
EXTRA WORK SPACE FOR PROBLEM 5
6. (10 points) Consider the following CMOS op-amp circuit. Find the small-signal voltage gain

\[ \frac{v_f}{v_{id}} = \left\{ g_{m1}(r_{02}|r_{04}) \right\} \left\{ -g_{m6}(r_{06}|r_{07}) \right\} \]

where \( v_{id} = (v_a - v_b) \).

HINT: Only perform required computations to save time.

\[ k_n = 0.5 \, \text{mA/V}^2, \quad k_p = 0.5 \, \text{mA/V}^2, \quad V_{tn} = 1 \, \text{V}, \quad \text{and} \quad V_{tp} = -1 \, \text{V}, \]

where \( k_n = \mu_n C_{ox} W/L \) and \( k_p = \mu_p C_{ox} W/L \).

\( |V_A| = 50 \, \text{V} \) all transistors.

For Q6 \( k_p = 1 \, \text{mA/V}^2 \).

Ignore the channel-length modulation effect (\( \lambda = 0 \)) in any DC computations.

EXTRA WORK SPACE FOR PROBLEM 6