ECE 4430 Midterm Exam
Fall 2017

Each question is worth 3 points.
All of your answers need to be on this sheet.
Only the final answers, as indicated by the question, will be considered correct for each question.
You will only turn in this single sheet.

1. _______________  12. _______________  23. _______________
2. _______________  13. _______________  24. _______________
3. _______________  14. _______________  25. _______________
4. _______________  15. _______________  26. _______________
5. _______________  16. _______________  27. _______________
6. _______________  17. _______________  28. _______________
7. _______________  18. _______________  29. _______________
8. _______________  19. _______________  30. _______________
9. _______________  20. _______________  31. _______________
10. _______________ 21. _______________  32. _______________
11. _______________ 22. _______________  33. _______________
A few items to be used for this exam:

EKV equation in saturation, including $\sigma$:

$$I = 2 I_{th} \ln^2(1 + \exp(\kappa(V_g - V_{T0}) - V_s - \sigma V_d)/(2U_T))$$

For $z = \ln^2(1 + e^y)$, $dz/dx$ (at $y = 0$) = 0.5 $dy/dx$.

Parameters for devices (unless given otherwise)

$V_{T0} = 0.3V$

$K' = 0.14 \text{mA} / \text{V}^2$

$I_{th}' = 125\text{nA}$

$\kappa = 0.7$

$\sigma = 0.001$, $V_A = 25V$ (L = 800nm)

Transistors are devices in a 200nm minimum (drawn) channel length process.

For drawn grids, a single grid step is 100nm.

$C_{ox} = 0.1fF / (100nm)^2$

Overlap capacitance = 0.1fF / (100nm)

Area source-drain capacitance at zero bias = 0.01fF / (100nm)$^2$

Perimeter source-drain capacitance at zero bias = 0.003fF / (100nm)
Small Signal Model Questions

You have a circuit design you want to bias right at the threshold current for your particular application. Use the value of \( \sigma \) given (0.001, or \( V_A = 25V \)), which is consistent for all regions of operation. Choose the closest answer wherever necessary.

1. How would you size your device (nearest size) if you wanted a bias current of 1\( \mu \)A operating at right at threshold?
   a. \( W/L = 2 \)
   b. \( W/L = 4 \)
   c. \( W/L = 8 \)
   d. \( W/L = 16 \)
   e. \( W/L = 32 \)

2. What is your transconductance (change in channel current for change in gate voltage) for this 1\( \mu \)A bias current at threshold?
   a. 5 \( \mu \)A/V
   b. 10 \( \mu \)A/V
   c. 14 \( \mu \)A/V
   d. 20 \( \mu \)A/V

3. What is your source conductance (change in channel current for change in source voltage) for this 1\( \mu \)A bias current at threshold?
   a. 5 \( \mu \)A/V
   b. 10 \( \mu \)A/V
   c. 14 \( \mu \)A/V
   d. 20 \( \mu \)A/V

4. What is your output resistance ( \( 1 / \) change in channel current for change in drain voltage) for this 1\( \mu \)A bias current at threshold?
   a. 5M\( \Omega \)
   b. 10M\( \Omega \)
   c. 25M\( \Omega \)
   d. 50M\( \Omega \)
   e. 100M\( \Omega \)

5. (A = true, B = False) If one use \( W/L = 1 \) (still for a 1\( \mu \)A bias), the saturated transistor is operating with subthreshold currents.

6. What is the transconductance of the MOSFET with \( W/L=1 \) for a 1\( \mu \)A bias?
   a. 5 \( \mu \)A/V
   b. 7 \( \mu \)A/V
   c. 10 \( \mu \)A/V
   d. 14 \( \mu \)A/V
   e. 20 \( \mu \)A/V

7. (A = true, B = False) For our devices operating with 1\( \mu \)A bias current, the output resistance of the transistor biased at threshold current (saturation) would be the same for the device at \( W/L=1 \) (saturation).

8. (A = true, B = False) For our devices, the transistor gain would be the same between the transistor biased at threshold current would be the same for the device at \( W/L=1 \) and operating in saturation (both at 1\( \mu \)A bias current).
Transistor Layout Questions

These questions will refer to the following MOSFET transistor layouts. Transistors are biased with subthreshold currents (10nA) unless otherwise mentioned.

9. The overlap capacitance (Cdg):
   a. 0.2fF
   b. 0.4fF
   c. 0.6fF
   d. 0.8fF
   e. 1fF

10. The overlap capacitance (Cdg):
    a. 0.3fF
    b. 0.6fF
    c. 1.2fF
    d. 1.8fF
    e. 2.4fF

11. Capacitance from your drain region to substrate (Cdb):
    a. 0.17fF
    b. 0.23fF
    c. 0.29fF
    d. 0.32fF
    e. 0.41fF

12. Capacitance from your drain region to substrate (Cdb):
    a. 0.17fF
    b. 0.23fF
    c. 0.29fF
    d. 0.32fF
    e. 0.41fF

13. Capacitance from your source region to substrate (Csb):
    a. 0.17fF
    b. 0.23fF
    c. 0.29fF
    d. 0.33fF
    e. 0.41fF

14. Capacitance from your source region to substrate (Csb):
    a. 0.3fF
    b. 0.6fF
    c. 1.25fF
    d. 2.5fF
    e. 5fF

15. Capacitance looking into the Gate (Cgb) (subthreshold bias current):
    a. 0.14fF
    b. 0.27fF
    c. 0.54fF
    d. 1.2fF
    e. 1.8fF

16. Capacitance looking into the Gate (Cgb) (subthreshold bias current):
    a. 4fF
    b. 6fF
    c. 8fF
    d. 10fF
    e. 12fF
17. Transistor W/L
   a. 1
   b. 2
   c. 4
   d. 8
   e. 16

18. Transistor W/L
   a. 1
   b. 2
   c. 4
   d. 8
   e. 16

19. (A = true, B = False): We can use $V_{gs}$ because for a MOSFET in a bulk CMOS process, the gate and source have the equal, although different sign, effects on the transistor surface potential.
Basic Transistor Circuit Questions

These questions will refer to the following MOSFET transistor circuits. C = 100fF. Vdd = 1.5V. Use W/L = 800nm / 800nm unless otherwise directed.

20. Circuit Type
   a. Common Gate 1
   b. Common Source
   c. Common Gate 2
   d. Common Drain

22. W/L (M2) required to obtain a corner frequency of 100MHz for a bias current of 2µA. (ignore parasitic capacitors)
   a. 1
   b. 2
   c. 4
   d. 8
   e. 16

24. Corner frequency (20nA bias current)
   a. 1.25MHz
   b. 2.5MHz
   c. 5MHz
   d. 10MHz
   e. 20MHz

26. What is the value for Vτ (20nA bias current)
   a. 0.23V
   b. 0.27V
   c. 0.3V
   d. 0.33V
   e. 0.37V

21. Circuit Type
   a. Common Gate
   b. Common Source
   c. Common Gate 2
   d. Common Drain

23. Minimum W/L (M1=M2) possible to obtain a corner frequency of 1MHz for a bias current of 2µA. (ignore parasitic capacitors)
   a. 1
   b. 2
   c. 4
   d. 8
   e. 16

25. Circuit Gain (Magnitude, 20nA bias current)
   a. 175
   b. 350
   c. 700
   d. 1400
   e. 2800

27. What minimum length would be required for a gain (magnitude) over 1000?
   a. 1000nm
   b. 1500nm
   c. 2000nm
   d. 2500nm
   e. 3000nm
Another Transistor Circuit Question

This question uses the following circuit.  
\( C = 10\text{pF} \).

![Circuit Diagram]

28. Circuit Type  
a. Common Gate 1  
b. Common Source  
c. Common Gate 2  
d. Common Drain

29. Gain from \( V_{in} \) to \( V_{out} \) for a subthreshold bias current  
a. 10  
b. 1  
c. 0.1  
d. 0.01  
e. 0.001

30. Corner Frequency for \( I_{ref} = 16\text{nA} \)  
a. 100Hz  
b. 1kHz  
c. 10kHz  
d. 100kHz  
e. 1MHz

31. For \( I_{ref} \) at 10nA, what is the change in output voltage if this current \( (I_{ref}) \) moves to 20nA?  
a. -40mV  
b. -20mV  
c. 0  
d. 20mV  
e. 40mV

32. (A = true, B = False): For frequencies above the corner frequency, the gain from \( V_{in} \) to \( V_{out} \) increases with frequency.

33. What is the minimum W/L (M2) to have a corner frequency of 1MHz?  
a. 0.1  
b. 1  
c. 10  
d. 100  
e. 1000