Instructions: This is a closed book, closed note exam. Calculators are not permitted. If you have a question, raise your hand and I will come to you. Please work the exam in pencil and do not separate the pages of the exam. For maximum credit, show your work.
Good Luck!

Your Name (***please print***) ____

1	2	3	4	total
30	20	30	20	100

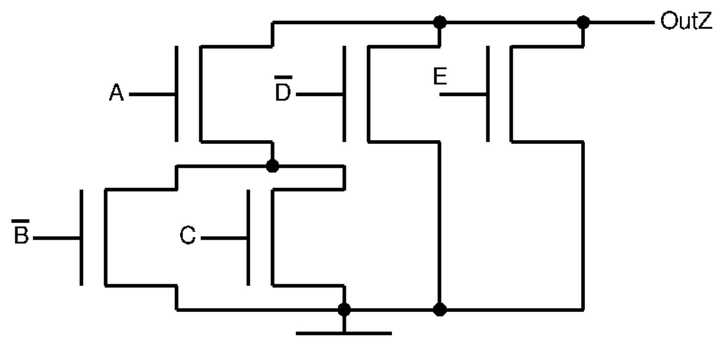
Problem 1 (3 parts, 30 points) Switch-level Design

Part A (24 points) For each expression below, create a switch level implementation using N and P type switches. Assume both inputs and their complements are available. Your design should contain no shorts or floats. Use as few transistors as possible.

OUTx = $\overline{A}\cdot B\cdot\left(C+\overline{D}\right)+E\cdot\overline{F}\cdot G$

OUTy = $\overline{\left(X+\overline{Y}\cdot\overline{Z}+W\right)\cdot\left(\overline{P}+Q\cdot R\right)\cdot S}$

Part B (6 points) Given the pull-down network below, draw the missing pull-up network so that the circuit contains no floats or shorts. Also, write the Boolean expression computed by the completed circuit. (The expression should have complements only over the individual input signals, not over subexpressions.)



Out$_Z$ = ______________________________

Problem 2 (3 parts, 20 points) Boolean Algebra

Part A (5 points) Transform the following Boolean expression to a form where it can be implemented using switches (i.e., there should only be bars over input variables, not over operations). The behavior of the expression should remain unchanged. **Do not implement**.

$$Out_A = \overline{\overline{A}\cdot\overline{B}}\cdot\overline{C}+D\cdot\overline{\overline{E\cdot\overline{F}}\cdot G}$$

$Out_A =$ ____________________

Part B (6 points) Derive a canonical sum of products (using minterms) and a product of sums (using maxterms) expression for the truth table below.

A	B	C	$F_{(A,B,C)}$
0	0	0	0
1	0	0	1
0	1	0	1
1	1	0	0
0	0	1	1
1	0	1	0
0	1	1	1
1	1	1	1

Standard $SOP_{(MINTERMS)}$ = ____________________

Standard $POS_{(MAXTERMS)}$ = ____________________

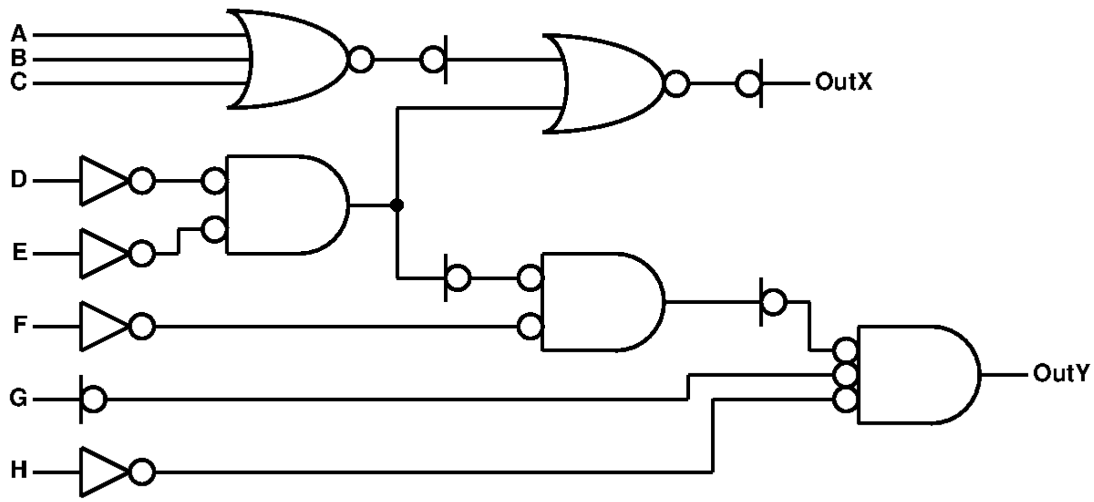
Part C (9 points) Translate the following standard sum of products (which uses minterms) to the equivalent standard product of sums (using maxterms) by first filling in the truth table below and then deriving the standard product of sums from it.

Standard $SOP_{(MINTERMS)}$ = $\overline{A}\,\overline{B}\,C+A\,\overline{B}\,C+A\,\overline{B}\,\overline{C}+A\,B\,\overline{C}+A\,B\,C$

A	B	C	$F_{(A,B,C)}$
0	0	0	
1	0	0	
0	1	0	
1	1	0	
0	0	1	
1	0	1	
0	1	1	
1	1	1	

Standard $POS_{(MAXTERMS)}$ = ____________________

Problem 3 (3 parts, 30 points) Mixed Logic Reengineering



Part A (10 points) Write the output expression for the gate design shown above. Also determine the number of switches used in its implementation.

OUTx = ______________________

OUTy = ______________________

switches = ______________________

Part B (10 points) Reimplement the behavior below with a mixed logic design style using only NAND gates and inverters. Determine the number of switches used in this implementation.

switches = ______________________

Part C (10 points) Implement the following expression using *only* AND gates and inverters. Then determine the number of transistors required. Use proper mixed logic notation. Do not modify the expression. Do not assume complements of inputs are available.

$$Out_Z = \left(\overline{A} + \overline{B} \cdot C\right) \cdot \overline{\overline{B} \cdot C} \cdot D$$

\# switches = ____________________

Problem 4 (2 parts, 20 points) Karnaugh Maps

Part A (10 points) Given the following Karnaugh Map, circle and list all the prime implicants, indicating which are essential and write the simplified *sum-of-products* (SOP) expression.

	$\overline{B}$	$\overline{B}$	B	B
$\overline{A}$	1	0	1	1
A	0	1	1	0
	$\overline{C}$	C	C	$\overline{C}$

Prime implicants:	Essential? Yes	Essential? No
	❑	❑
	❑	❑
	❑	❑
	❑	❑
	❑	❑
	❑	❑
	❑	❑

simplified *SOP* expression ______________________________

Part B (10 points) Simplify the following SOP expression using a Karnaugh Map. Circle and list all the prime implicants, indicating which are essential and write the *product-of-sums* (POS) expression.

$$Out = \overline{A}\,\overline{B}\,C + A\,\overline{B}\,\overline{C} + A\,\overline{B}\,C$$

	$\overline{B}$	$\overline{B}$	B	B
$\overline{A}$				
A				
	$\overline{C}$	C	C	$\overline{C}$

Prime implicants:	Essential? Yes	Essential? No
	❑	❑
	❑	❑
	❑	❑
	❑	❑
	❑	❑
	❑	❑
	❑	❑

Simplified *POS* expression ______________________________