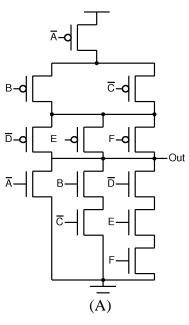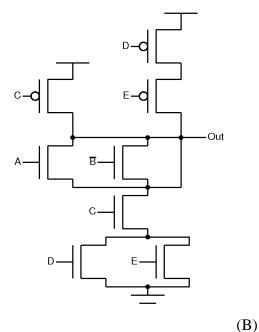Problem 1 (2 parts, 20 points)   Switch-level Design
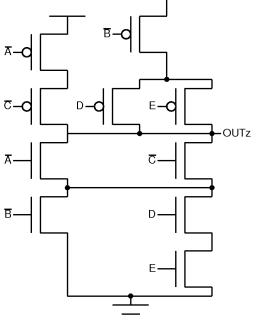
The three parts below contain (A) a pull up network, (B) a pull down network, and (C) an expression to be implemented. For (A) and (B), complete the missing complementary switching networks so the circuit contains no floats or shorts and write the Boolean expression computed by the completed circuit. For (C), design the entire switching network. Assume the inputs and their complements are available.

(A)

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

OUTy = $\overline{C} + \overline{D} \cdot \overline{E}$

(B)

OUTz = $A \cdot C + B \cdot (\overline{D} + \overline{E})$
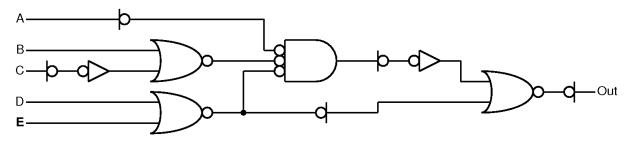
(C)

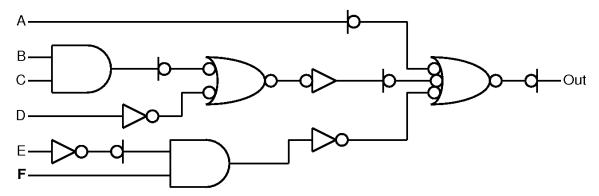Problem 2 (2 parts, 28 points)   Mixed Logic Reengineering

For the following expressions, implement the Boolean expression using the specified gate type. **Use correct mixed-logic notation. Do not simplify the expression**. You may use multi-input gates. Minimize the total transistors (switches) required.   When possible, use common subexpressions to reduce gate counts. Also determine the number of switches used in each implementation.

Part A (14 points) Implement $\overline{\overline{\overline{A} \cdot (B + \overline{C}) \cdot (D + E)}} + \overline{(D + E)}$ using only **NOR** and **NOT** gates.

     # switches =   **22T**

Part B (14 points) Implement $\overline{A} + \overline{\overline{\overline{(B \cdot C + D)}}} + \overline{E} \cdot F$ using only **AND** and **NOT** gates.

     # switches =   **34T**

Problem 3 (2 parts, 22 points)   Boolean Algebra

Part A (10 points) Transform each of the following Boolean expressions to a form where they are ready for switch level implementation (i.e., there should only be bars over input variables, not over operations). The behavior of the expression should remain unchanged. **Do not implement.**

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

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

$$Out_Y = \overline{R \cdot S + M \cdot \overline{N} \cdot P + \overline{L} \cdot \overline{\overline{K} \cdot J}}$$

$$(\overline{R} + \overline{S}) \cdot (\overline{M} + N + \overline{P}) \cdot (L + \overline{K} \cdot J)$$

Part B (12 points) For the behavior described by this truth table, (A) write the sum of products expression using minterms and (B) write the product of sums expression using maxterms.

A	B	C	Out
0	0	0	1
1	0	0	1
0	1	0	0
1	1	0	1
0	0	1	0
1	0	1	0
0	1	1	1
1	1	1	0

(A) SOP minterm expression $\overline{A} \cdot \overline{B} \cdot \overline{C} + A \cdot \overline{B} \cdot \overline{C} + A \cdot B \cdot \overline{C} + \overline{A} \cdot B \cdot C$

(B) POS maxterm expression $(A + \overline{B} + C) \cdot (A + B + \overline{C}) \cdot (\overline{A} + B + \overline{C}) \cdot (\overline{A} + \overline{B} + \overline{C})$
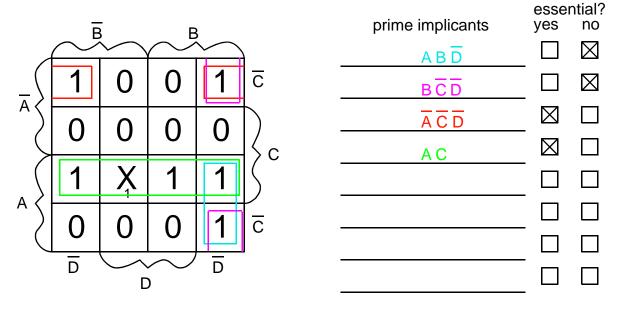
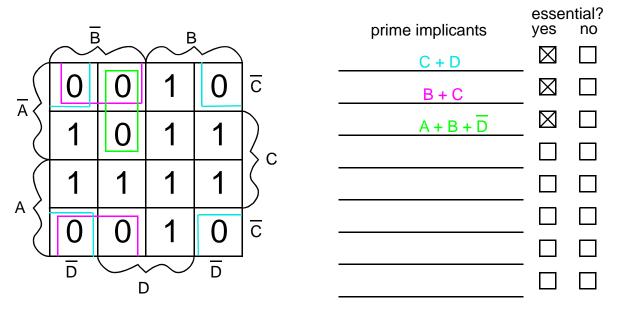Problem 4 (2 parts, 30 points)   Karnaugh Maps

Part A (15 points) Given the following Karnaugh Map, circle and list all the prime implicants for a **sum-of-products (SOP)** expression, indicating which are essential. Derive the simplified *SOP* expression.

prime implicants	essential? yes	no
A B $\overline{D}$	☐	☒
B $\overline{C}$ $\overline{D}$	☐	☒
$\overline{A}$ $\overline{C}$ $\overline{D}$	☒	☐
A C	☒	☐
	☐	☐
	☐	☐
	☐	☐
	☐	☐

simplified SOP expression $A \cdot C + \overline{A} \cdot \overline{C} \cdot \overline{D} + A \cdot B \cdot \overline{D}$ or $A \cdot C + \overline{A} \cdot \overline{C} \cdot \overline{D} + B \cdot \overline{C} \cdot \overline{D}$

Part B (15 points) For the following expression, derive a simplified **product of sums** expression using a Karnaugh Map. Circle and list all the prime implicants, indicating which are essential.

$$Out = (A + B + C) \cdot (\overline{A} + \overline{B} + C + D) \cdot (A + C + D) \cdot (A + B + \overline{C} + \overline{D}) \cdot (\overline{A} + B + C)$$

prime implicants	essential? yes	no
C + D	☒	☐
B + C	☒	☐
A + B + $\overline{D}$	☒	☐
	☐	☐
	☐	☐
	☐	☐
	☐	☐
	☐	☐
	☐	☐

simplified POS expression $(B + C) \cdot (C + D) \cdot (A + B + \overline{D})$

4