Limit your answers to the space provided. Wherever a box is provided for the answer, write your answer in the box. If you require more space than is provided, you are probably doing something wrong. Use the back of each page for any scratch work. Whenever necessary show your work for partial credit, otherwise no partial credit will be given.

<table>
<thead>
<tr>
<th>PROBLEM</th>
<th>POINTS</th>
<th>SCORE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>TOTAL</td>
<td>100</td>
<td></td>
</tr>
</tbody>
</table>
1 (10 Points)

Let $F(x,y,z)$ be a Boolean function defined as:

$$F(x,y,z) = (x \cdot y \cdot z)' \cdot (x + (y \cdot z')) \cdot (x + y)$$

Fill in the function table entries for $F$ below. Columns labeled $(x \cdot y \cdot z)'$, $(x + (y \cdot z'))$, and $(x + y)$ are included to help you fill in the column for $F(x,y,z)$ (and for partial credit if your answer for $F(x,y,z)$ is wrong).

<table>
<thead>
<tr>
<th>x</th>
<th>y</th>
<th>z</th>
<th>$(x \cdot y \cdot z)'$</th>
<th>$(x + (y \cdot z'))$</th>
<th>$(x + y)$</th>
<th>$F(x,y,z)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>
2. (15 Points)

The Karnaugh Map below for three-variable function $G(x,y,z)$ is shown below.

2a. (5 Points) Write $G$ in Sum-of-Minterm canonical form:

$$G(x,y,z) = \sum m(1,3,4,6,7)$$

2b. (5 Points) Write $G$ in Product-of-Maxterm canonical form:

$$G(x,y,z) = \Pi M(0,2,5)$$

2c. (5 Points) Write the complement of $G$ in Product-of-Maxterm canonical form:

$$G'(x,y,z) = \Pi M(1,3,4,6,7)$$
3. (15 Points)
Consider the 4-variable Boolean function $f(w,x,y,z)$ described by the K-Map below.

3a. (5 points) On the K-Map below, circle the Prime Implicants you would select for a minimum literal cover of $f(w,x,y,z)$:

Note that two less-than PIs have been deleted as well as one redundant PI.

3b. (10 points) Using the terms you circled above, write $f(w,x,y,z)$ in minimal literal Sum-of-Products form.

$$f(w,x,y,z) = y'z' + x'z' + w'y'z + wxz$$
4. **(10 Points)**
A Boolean function $Q(A,B,C,D)$ is implemented in a two-level NAND-NAND network with explicit inverters. The NAND gate logic diagram below shows the structure for function $Q$.

![NAND gate logic diagram](image)

Note that a NAND-NAND Network is in Sum-of-Products Standard Form. We write the equations by inspection.

**(10 points)** Write a Boolean expression for $Q(A,B,C,D)$ in the box below using only AND, OR, and NOT operators.

$Q(A,B,C,D) = A \cdot B + B \cdot C' + C \cdot D$

An alternate (and not as nice) form:

$Q(A,B,C,D) = [(A \cdot B)' \cdot (B \cdot C')' \cdot (C \cdot D)']'$
5 (20 Points)

Given the Boolean function:

\[ f(A,B,C,D) = AC + BC + A'B'C + BD + B'C'D' \]

5a). (10 points)  Draw the K-Map of the function in the map provided below.

Note that the NOR-NOR form is equivalent to a two-level Product-of-Sums Standard Form. We first write a minimum literal SOP form for the COMPLEMENT of \( f(A,B,C,D) \). Then we use DeMorgan's Law to complement the result to \( f(A,B,C,D) \) and convert to POS Standard Form.

\[ f''(A,B,C,D) = B \cdot C' \cdot D' + B' \cdot C \cdot D \]

\[ f(A,B,C,D) = (B \cdot C' \cdot D' + B' \cdot C \cdot D)' = (B' + C + D) \cdot (B + C + D') \]

5b). (10 points)  Implement \( f(w,x,y,z) \) in a minimum gate, TWO-LEVEL, NOR-NOR logic circuit. Assume that both true and complement values are available for input variables. DRAW YOUR CIRCUIT in the space below.

---

Quiz #2 Sect. #2  Page 6  February 17, 1997
6. **(15 Points)**

A function \( P(a,b,c,d) = \sum m(0,12,13,14,15) + \sum d(1) \).

Use the tabular method to find all the Prime Implicants of the function \( P(a,b,c,d) \), where the second summation is the don't care minterms.

Show your work clearly and circle all final prime implicants. The table below is set up for you to start the algorithm.

<table>
<thead>
<tr>
<th></th>
<th>a b c d</th>
<th></th>
<th>a b c d</th>
<th></th>
<th>a b c d</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0 0 0 0 ( \sqrt{} )</td>
<td></td>
<td>0 0 0</td>
<td></td>
<td>{null}</td>
</tr>
<tr>
<td>1</td>
<td>0 0 0 1 ( \sqrt{} ) (d)</td>
<td></td>
<td>null</td>
<td></td>
<td>null</td>
</tr>
<tr>
<td>12</td>
<td>1 1 0 0 ( \sqrt{} )</td>
<td></td>
<td>1 1 0 ( \sqrt{} )</td>
<td></td>
<td>1 1 ( \sqrt{} )</td>
</tr>
<tr>
<td>13</td>
<td>1 1 0 1 ( \sqrt{} )</td>
<td></td>
<td>1 1 ( \sqrt{} )</td>
<td></td>
<td>1 1 ( \sqrt{} ) (duplicate)</td>
</tr>
<tr>
<td>14</td>
<td>1 1 1 0 ( \sqrt{} )</td>
<td></td>
<td>1 1 ( \sqrt{} )</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>1 1 1 1 ( \sqrt{} )</td>
<td></td>
<td>1 1 ( \sqrt{} )</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
7). (15 points)

A prime implicant table for the function \(H(w,x,y,z)\) below has been filled in as the result of running a tabular prime implicant generation algorithm. Using the table, you will select a minimum literal cover and write an expression for the result. You may not need all the PI entries.

7a (10 points) For each prime implicant, **fill in the type of implicant** in the space provided using the following nomenclature:

- **EPI** = Essential Prime Implicant,
- **LTPI** = Less Than Prime Implicant,
- **SEPI** = Secondary Essential Prime Implicant
- **RPI** = Redundant Prime Implicant.

<table>
<thead>
<tr>
<th>PI \ Minterm</th>
<th>1</th>
<th>2</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>13</th>
<th>Type of Implicant</th>
</tr>
</thead>
<tbody>
<tr>
<td>(w' x')</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>EPI (m8, m11)</td>
</tr>
<tr>
<td>(y' z)</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>EPI (m1, m13)</td>
</tr>
<tr>
<td>(w' x z)</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>LTPI (m5)</td>
</tr>
<tr>
<td>(w' x y)</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>SEPI (m7)</td>
</tr>
<tr>
<td>(w' y z')</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>SEPI (m2)</td>
</tr>
<tr>
<td>(x' y z')</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>LTPI (m10)</td>
</tr>
<tr>
<td>(Check)</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td>(For minterm usage)</td>
</tr>
</tbody>
</table>

7b. (5 points) Write \(H(w,x,y,z)\) in minimal literal Sum-of-Products form.

\[
H(w,x,y,z) = w\cdot x' + y'\cdot z + w'\cdot x\cdot y + w'\cdot y\cdot z'
\]