Switch level circuits:

1) (15 total point) For the 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. Implement the equations exactly as they are (no simplifying).

$$\text{Out}_x = (C + \overline{D}) \cdot (E + F) \cdot \overline{A} \cdot B$$
Switch-Ready Expressions:

2) (15 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**, just show the new Boolean equation without any "big bars".

\[
\text{Outx} = (A + B) (C + D) (E + F)
\]

\[
\overline{A + B} + \overline{C + D} + \overline{E + F}
\]

\[
\overline{A + B} + \overline{C + D} + (E + F)
\]

\[
\overline{A + B} + (\overline{C} \cdot \overline{D}) + (E + F)
\]

\[
\overline{A + B} + \overline{C} \cdot \overline{D} + (E + F)
\]
3) Part A (15 points) Write the boolean output expression for the gate design shown below. Also determine the number of switches used in its implementation.

\[
\text{Out} = \overline{((C+D) \cdot E) + \overline{F} \cdot \overline{G}} + (H+I)
\]

\[
J = (C+D)E + \overline{F}G + \overline{H}I
\]

number of switches \( = 40 \)

\[
6 \times 2 + 7 \times 4 = 40
\]
3) Part B (15 points) Implement the following expression using only two input OR gates and inverters so as to minimize the number of switches required. Then determine the number of switches required. **Use proper mixed logic notation.** Do not modify the expression, do not simplify the expression. Do not assume complements of inputs are available.

\[
\text{Out}= \left( (A + B + C) \cdot \overline{D} + E \cdot F \right) \cdot G
\]

Number of switches

\[
6 \times 6 + 5 \cdot 2 = 36 + 10 = 46
\]
Karnaugh Maps:

4) (15 points) For the following expression, derive a simplified sum of products expression using a Karnaugh Map. Circle and list ALL the prime implicants, indicating which are essential.

\[ A \cdot \overline{C} + A \cdot B \cdot \overline{C} + B \cdot \overline{D} + B \cdot C \cdot D \]

<table>
<thead>
<tr>
<th>prime implicants</th>
<th>essential?</th>
</tr>
</thead>
<tbody>
<tr>
<td>(A \cdot \overline{C})</td>
<td>(\xmark)</td>
</tr>
<tr>
<td>(B \cdot \overline{D})</td>
<td>(\xmark)</td>
</tr>
<tr>
<td>(B \cdot \overline{C})</td>
<td>(\xmark)</td>
</tr>
<tr>
<td>(A \cdot B)</td>
<td>(\xmark)</td>
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</tbody>
</table>

Simplified sum of products

\[ A \cdot \overline{C} + B \cdot \overline{C} + B \cdot \overline{D} \]
5) (10 points) Determine the canonical product of sums (using maxterms) expressions for the truth table below:

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>C</th>
<th>OUT</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
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<td>0</td>
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</tbody>
</table>

\[ \text{POS (maxterms)} = \overline{A + B + C} \overline{A + B + C} \overline{A + B + C} \overline{A + B + C} \]

6) (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.

\[ \text{out} = (A+B+C) (A+B+C) (A+B+C) (A+B+C) (A+B+C) \]

![Karnaugh Map Diagram]

<table>
<thead>
<tr>
<th>prime implicants</th>
<th>essential?</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \overline{A + C} )</td>
<td>( \checkmark )</td>
</tr>
<tr>
<td>( A + C )</td>
<td>( \times )</td>
</tr>
<tr>
<td>( B + \overline{C} )</td>
<td>( \times )</td>
</tr>
<tr>
<td>( A + B )</td>
<td>( \times )</td>
</tr>
</tbody>
</table>

\[ \text{Simplified product of sums} = \overline{(A + C)(A + C)(B + C)} \overline{(A + C)(A + C)(B + B)} \]