1. Group ALL expressions in the list below into equivalent subgroups. Note that some expressions may not be equivalent to anything (except themselves) so they will be the only member of their subgroup.

\[
\begin{align*}
  x\bar{y} + yz \\
  x \oplus yz \\
  xz + \bar{x}\bar{z} \\
  x\bar{y} + xz + yz \\
  \bar{x} \oplus y \oplus z \\
  \overline{x \oplus z} \\
  x\bar{y} + x\bar{z} + \bar{xy}z
\end{align*}
\]

2. Consider the Boolean function \( f(x, y, z, w) = x'y'z' + xyz'w' + zw' + yz'w + yzw' \)

2a. Implement \( f \) with a NAND-NAND array (i.e. a NAND of NAND’s of literals) \textbf{MINIMIZING} the number of product terms but disregarding any hazards.

2b. Suppose you are now told to eliminate the possibility of any timing hazards as well. Would you change your answer in part 2a., and, if so, how?

3a. If you are using the TTL logic family and you forget to connect an input, what value does the chip use for the input?

3b. Implement the Boolean function \( g(a, b, c, d) = \Pi(0, 1, 4, 5, 6, 7, 11) \) as a minimized product of sums (POS).

4a. What is Ohm’s law and how does it relate the voltage, current, and resistance in a direct current (D.C.) circuit?
4b. Explain how you would design a combinatorial circuit which would add two 4-bit numbers $b_3b_2b_1b_0$ and $c_3c_2c_1c_0$. Since the circuit will be somewhat repetitive, it is actually only necessary to draw part of the circuit and indicate how the rest would be wired.

5a. In CompSci 320 Lab you put a resistor (of about 300 ohms) in series with your power-detecting LED. What function does this resistor serve? Is it really necessary?

5b. Suppose that you have implemented a Boolean function, minimized it as a sum of products, and you notice that each group of ones is separated from the others by at least a 2-bit change. Is the circuit safe from hazards. Why or why not?

6. Which of the following statements are always true for Boolean expressions?

\[ x + xy = x + y \]
\[ xy + yz + xz = x + y + z \]
\[ x + \bar{x}y = x \]
\[ \bar{x} \oplus \bar{y} = x \oplus y \]
\[ x + yz = (x + y)(x + z) \]