• Do not start the exam until you are told to.
• Turn off any cell phones or pagers.
• Write your name and PID at the top of every page. Do not separate the pages.
• This is a closed-book, closed-notes, no-calculator exam. You may only refer to one page of your own notes.
• Do not look at anyone else’s exam. Do not talk to anyone but an exam proctor during the exam.
• If you have a question, raise your hand and an exam proctor will come to you.
• You have 80 minutes to finish the exam. When the time is finished, you must stop writing.
• Write your answers in the space provided.
• To get the most partial credit, clearly and neatly show all steps of your work.

1. 20 points
2. 10 points
3. 10 points
4. 25 points
5. 20 points
6. 15 points
7. 10 points

Total (100 points)
1. (20 points)
Draw the CMOS implementation of function
\[ F(A, B, C) = (A + B + C)(\overline{A} + B)(\overline{A} + B + C). \]
Try to minimize the number of transistors involved.
Place the arrangement of transistors within the dashed boxes below, making sure to make appropriate connections to the ground, the high voltage, the inputs A, B, C, and the output F.
2. (10 points)
Consider the following two Boolean functions (10 marks)

\[
F(X, Y, Z) = (\overline{X})(\overline{Z}) + Z + Z(\overline{Y}) + (X + 0)(\overline{Z} + Y)(\overline{Z} + \overline{Y})(Y + 1)
\]

\[
G(X, Y, Z) = X(\overline{Z})
\]

Using the theorems of Boolean algebra, prove that \( F(X, Y, Z) = G(X, Y, Z) \)
3. (10 points)
Implement this function using only NOR gates. How many NOR gates will you need?
4. (25 points)
Consider the following Boolean function
\[ F(A, B, C, D) = m(0, 4, 5, 10, 12, 13, 14) + d(3, 8, 15) \]
a) What is the corresponding KMap for \( F \)?

b) Identify all prime implicants of \( F \).

c) What are the essential prime implicants.

d) Give one minimized Sum-of-Products form for \( F \).
5. (25 points)
Implement F1 and F2 using a minimum number of logic gates. (Hint: share the gates between the two functions)
F1(A, B, C, D) = S m(5, 7, 10, 13, 14, 15)
F2(A, B, C, D) = S m(0, 2, 4, 5, 6, 7, 8, 12, 13, 15)
6. (20 points)
F(A,B,C,D) = \Pi M(2, 3, 6, 8, 9, 12, 13, 14)

a) Minimize the function F, show the minimum function in POS form.

b) Are there any static-0 hazards? If so, show where, and how you'd fix that.
7. **(10 points)**

(Bonus) Implement the function $F$ using the 8 input multiplexor as shown below.

$F(A, B, C, D) = \Sigma m(2, 3, 7, 9, 10, 13, 14) + d(12, 15)$
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