Problem No. 1: (25 points)
What is the difference between a POS expression and an SOP expression?

SOP

A Boolean expression consisting of a set of min-terms. The expression is built with each product term that gives a high, or 1, output. The final expression is obtained by adding the relevant product terms.

POS

A Boolean expression consisting of a set of max-terms. The expression is built with each input combination that results in a low, or 0, output. The final expression is obtained by multiplying the relevant sum terms.

For the truth table given below, derive a standard SOP and a standard POS expression. No simplification required.

SOP

$$AB\bar{C}\bar{D}+A\bar{B}\bar{C}D+\bar{A}\bar{B}\bar{C}\bar{D}+\bar{A}\bar{B}\bar{C}D+\bar{A}\bar{B}CD+\bar{A}B\bar{C}D+\bar{A}BC\bar{D}$$

POS

$$\cancel{(\bar{A}+\bar{B}+C+D)(\bar{A}+B+\bar{C}+\bar{D})(\bar{A}+B+C+D)(A+\bar{B}+\bar{C}+\bar{D})}$$

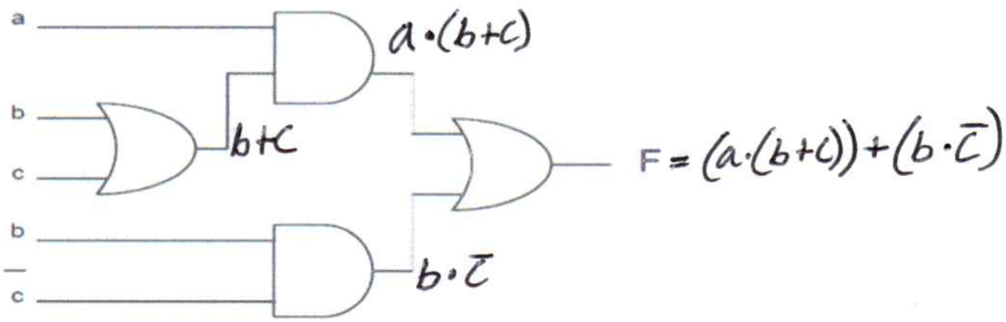
$$\cancel{(A+\bar{B}+C+D)(A+\bar{B}+C+D)(A+B+\bar{C}+D)(A+B+C+\bar{D})}$$ [illegible]

$$(A+B+\bar{C}+D)(A+\bar{B}+C+D)(A+\bar{B}+\bar{C}+\bar{D})(\bar{A}+B+C+D)(\bar{A}+B+\bar{C}+D)$$
$$(\bar{A}+B+\bar{C}+\bar{D})(\bar{A}+\bar{B}+C+\bar{D})(\bar{A}+\bar{B}+\bar{C}+D)(\bar{A}+\bar{B}+\bar{C}+\bar{D})$$

A	B	C	D	F
0	0	0	0	1
0	0	0	1	1
0	0	1	0	0
0	0	1	1	1
0	1	0	0	0
0	1	0	1	1
0	1	1	0	1
0	1	1	1	0
1	0	0	0	0
1	0	0	1	1
1	0	1	0	0
1	0	1	1	0
1	1	0	0	1
1	1	0	1	0
1	1	1	0	0
1	1	1	1	0

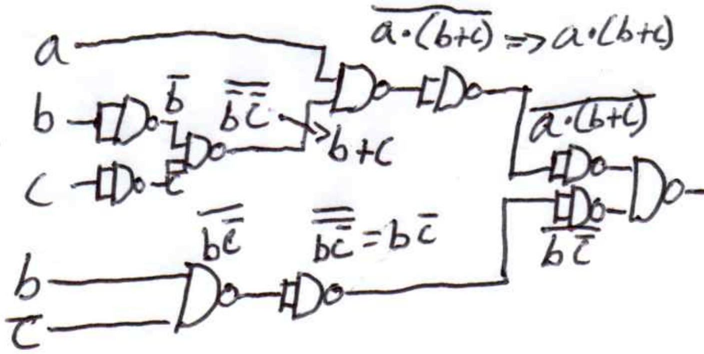
Problem No. 2: (25 points)

Find the Boolean expression for the output of the circuit F. Do not simplify.



Why are NAND gates and NOR gates called *Universal Gates*? For the circuit given above, implement the logic using *only NAND gates*.

I wrote this out to understand it better.



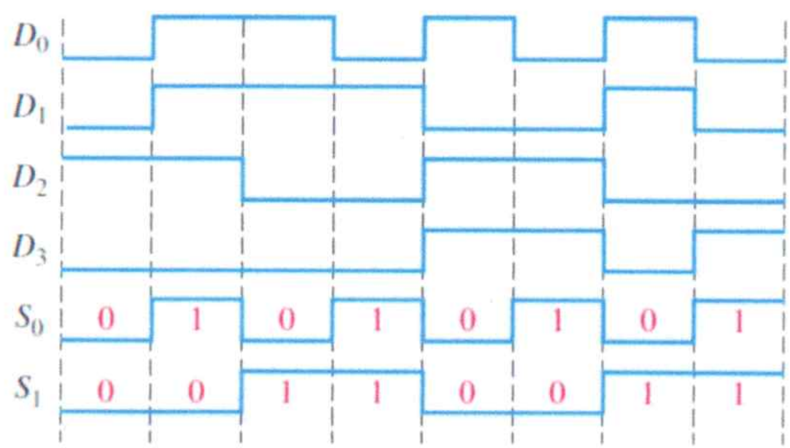
$$\overline{\overline{a\cdot(b+c)}\cdot\overline{b\bar{c}}}$$

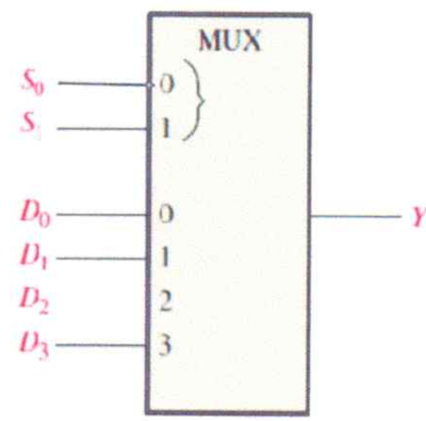
$$\overline{\overline{a\cdot(b+c)}} + \overline{\overline{(b\bar{c})}}$$

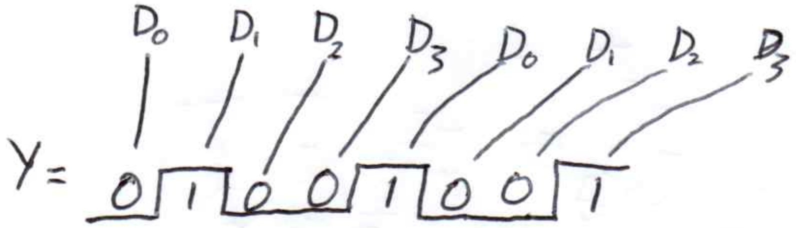
$$\boxed{a\cdot(b+c)+(b\bar{c})}$$

NAND and NOR gates are called the universal gates because they can perform all the basic functions AND, OR, NOT. All logic circuits can be converted into NAND/NOR logic.

Problem No. 3: (25 points)
The data input and data select waveforms as shown below are applied to the 1 of 4 multiplexer as shown in figure below. Determine the ***output waveform Y*** in relation to the inputs.

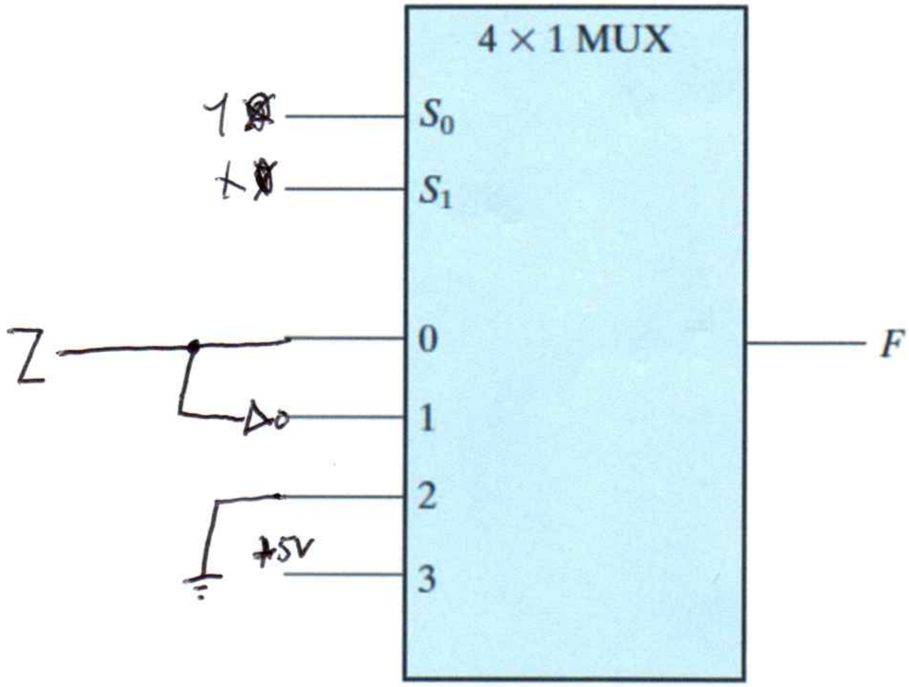






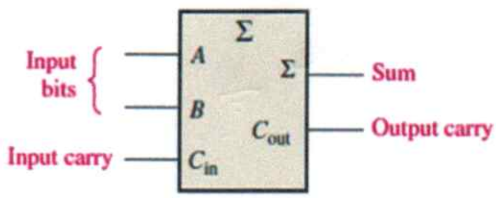
Consider the logic function described by the following truth table. ***Implement*** the logic function specified in the truth table by using a ***1-of-4 MUX***. Make sure to clearly label all inputs and outputs.

	X	Y	Z	F	
0	0	0	0	0	F=Z
	0	0	1	1	
1	0	1	0	1	F=$\bar{Z}$
	0	1	1	0	
2	1	0	0	0	F=0
	1	0	1	0	
3	1	1	0	1	F=1
	1	1	1	1	


4 × 1 MUX
S_0
S_1
0
1
2
3
F
Z
+5V

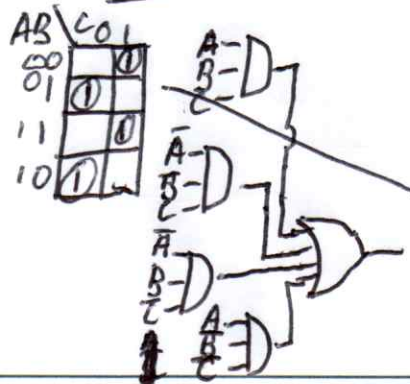
Problem No. 4: (25 points)
Figure below shows a schematic of a full-adder and the corresponding truth table.

Based on the truth table, write the SOP expressions for the Σ and C_{out} of the full-adder.



A	B	C_{in}	C_{out}	Σ
0	0	0	0	0
0	0	1	0	1
0	1	0	0	1
0	1	1	1	0
1	0	0	0	1
1	0	1	1	0
1	1	0	1	0
1	1	1	1	1

Σ



C_{out}

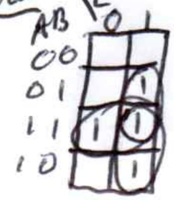
$\bar{A}BC_{in} + A\bar{B}C_{in} + AB\bar{C}_{in} + ABC_{in}$

Σ

$\bar{A}\bar{B}C + \bar{A}B\bar{C} + A\bar{B}\bar{C} + ABC$

Use a Karnaugh map to minimize the expressions and show how to implement implement the circuits for the Σ and C_{out} using inverters and AND-OR logic.

C_{out}



$BC + AC + AB$