ECE111: Digital Circuits

Practice Problem II

1. Assume that you have four switches S_1,S_2,S_3,S_4 and two LEDs out of which one is Green (**G**) and the other is Red (**R**). LED **R** and **G** will glow according to the following switching scheme. Design a combinational circuit for that.
    a) If S_1 alone is ON, then both the LED **R** and **G** should be OFF. If S_2 alone is ON, then **R** should be OFF and **G** should be ON. If S_3 alone ON, then **R** should be ON and **G** should be OFF. If S_4 alone ON, then **R** should be ON and **G** should be ON.Assume that more than one switch is not ON at the same time.
    b) Now consider, if any of two switches say, S_n and S_{n+1} are simultaneously ON, then Switch S_{n+1} should be given higher priority than S_n
    c) If any of three switches S_n ,S_{n+1} and S_{n+2} are simultaneously ON, then Switch S_{n+2} should be given higher priority than other switch.
    d) If all the switches are ON, S_4 should be given highest priority than any other switch.

2. Buses leave the terminal every hour on the hour unless there are fewer than 10 passengers or the driver is late. If there are fewer than 10 passengers the bus will wait for 10 minutes or the number of passengers increases to 10. If the bus leaves on time it can travel at 60 kmph. If the bus leaves late or if it rains the bus can travel only at 30kmph. Under what condition will the bus travel at 60 kmph? Construct a circuit to get an output 1 for the bus to travel at 60 kmph using NAND gates.

3. A robot has <u>four</u> permitted directions of movement and <u>three</u> possible speed settings. Let the direction control and the speed control be applied through two bits each:

    $\mathbf{D_1D_0}$ = 00(forward) / 11(reverse) / 01(right) / 10(left), and

    $\mathbf{S_1S_0}$ = 00(zero) / 01(low) / 10(medium) / 11(high).

    It is desired to have an electronic protection system to ensure that the robot can move at high speed for forward movement <u>only</u>, and reverse <u>only</u> at low speed. This will have to be achieved by generating an output bit **P** which should go HIGH if any of these two conditions is violated, and then using **P** to shut off the power to the robot. e down the Boolean expression for the output Pin the sum of products form in terms of $\mathbf{D_1}, \mathbf{D_0}, \mathbf{S_1}, \mathbf{S_0}$.

4. The control unit of a chemical process is required to control the temperature and the pressure inside a reactor by binary (ON/OFF) control of a Heater (H) and an inlet Valve (V) according to the following logic:

    Heater is ON if the Temperature is Low and the Pressure is not HIGH.

    Valve is Open if Pressure is Low and Temperature is not LOW.

    In addition, the control unit has also to sound an Alarm (A) if the temperature and the pressure are either both LOW or both HIGH. Assign two binary variables **TL** and **TH** to represent the three possible ranges – LOW, NORMAL and HIGH – of temperature and two binary variables **PL** and **PH** to represent the three possible ranges of pressure. Obtain Boolean expressions for the output variables **H**, **V** and **A** in terms of **TL**, **TH**, **PL** and **PH**.

5. A treasure box is continuously monitored by a logic circuit, which has three keys (x1, x2 and x3). The circuit can open the treasure box whenever two or more keys used. Implement this circuit functionality using only NAND gates with minimal cost.

6. A Boolean function ***F1*** and ***F2*** of four binary variables ***A***, ***B***, ***C***, ***D*** has the following SOP and POS expressions:

   F1(A,B,C) = A'•B + A•B' + C'•D and ***F2(A,B,C) = (A + B)•(C' + D')•(C + D).***

   a. Obtain the expression for ***F1*** in the CSOP form.

   b. Obtain the expression for ***F1*** in the minimised POS form.

   c. Repeat the same process for function ***F2*** as well.

7. Using postulates,

   a. find minimum SOP expression for the function,

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

   b. Prove that $B \oplus (A \cdot B + B \cdot C + A' \cdot C) = A' \cdot (B \oplus C)$

8. Given following Truth Table, Write the CSOP and CPOS for outputs. Minimize the output functions by using Postulates. Use De Morgan's laws and implement **outputs** using only two input NAND Gates.

   a.

Input			Outputs	
A	B	C_{in}	S	C_{out}
0	0	0	0	0
0	0	1	1	0
0	1	0	1	0
0	1	1	0	1
1	0	0	1	0
1	0	1	0	1
1	1	0	0	1
1	1	1	1	1

   b.

Inputs				Output
A	B	C	D	F
0	0	0	0	0
0	0	0	1	0
0	0	1	0	0
0	0	1	1	1
0	1	0	0	0
0	1	0	1	0
0	1	1	0	0
0	1	1	1	1
1	0	0	0	0
1	0	0	1	0
1	0	1	0	0
1	0	1	1	1
1	1	0	0	1
1	1	0	1	1
1	1	1	0	1
1	1	1	1	1

9. Prove that A'B(D' + C'D) + B(A + A'CD) = B

10. Assuming zero delay between input and output of each gate, complete the timing diagram of the following circuit. (In answer sheet, show all 6 timing diagrams corresponding to boolean variables a,b,c,x,y,f on the same page).