ENGR101

ENGINEERING TECHNOLOGY

Practice Exam (June 12, 2024)

Time allowed: 120 MINUTES

CLOSED BOOK
You will be supplied with additional printed resources that you may use.
(Appendix section on pages 10-11)

Permitted materials: Non-programmable calculators are allowed.

Only printed dictionaries are allowed.

Printed foreign to English language dictionaries are allowed.

Instructions: There are 4 questions. Attempt ALL questions.

Space for working out your solutions is provided at the end of every question.

Question	Topic	Allocated Marks	Obtained Marks	Comments
1	Number Systems	25		
2	Boolean Algebra and K-Maps	25		
3	Logic Circuit Application	25		
4	Logic Circuit Application	25		
	TOTAL	**100**		

ID Number: ……………………………..….

This blank space can be used to write your answers in case there is insufficient space in the allocated space after each question.

ID Number: ……………………………….

Question 1 – Number systems **25 marks**

a) Convert the binary number 0 0 1 0 1 0 1 0 to its decimal number equivalent. (3 marks)

0	**0**	**1**	**0**	**1**	**0**	**1**	**0**

Answer : 4 2

Show your calculations in the space below. Write your answer in the space provided above.

2^5+2^3+2^1=42

b) Convert the decimal number 170 to its hexadecimal number equivalent. (2 marks)

$(170)_{10}$

		A	**A**

Show your calculations in the space below. Write your answer in the grid shown above starting from the right-hand side box.

170/16 = 10 R10 A
10/16 = 0 R10 A

ID Number: ……………………………..….

c) Convert the following octal number to a decimal number. (2 marks)

123_8 = 83

Show your calculations in the space below. Write your answer in the space provided above.

1x8^2+2x8^1+3 = 83

d) Complete the following **binary** number **subtraction**: (4 marks)

1 0 0 1 0 1 1 - 1 1 0 1 0 1

```
   01
0  10  10 0 10
1  0  0  1 0 1 1     = 75
   1  1  0 1 0 1     = 53
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    0 1  0  1 1  0   = 22
```

e) Convert the decimal number $(-12)_{10}$ to 6-bit binary representation using (9 marks)

i. signed magnitude
+12 = 001010

-12= 101010

ii. one's complement
-12= 110101

iii. two's complement
-12= 110110

f) Represent $(0.45)_{10}$ in binary. Stop after 4 decimal places and find the % rounding error. (5 marks)

0.01 1100 1100 1100 1100

Stopping after 4 decimal places is 0.0111 = 0.25+0.125+0.0625=0.4375
Error = (0.45-0.4375)/0.45 = 0.0278 = 2.78%

Question 2 – Boolean Algebra and K-Maps **25 marks**
(Refer to Appendix for Boolean Laws summary)

a) Use Boolean algebra to simplify (5 marks)

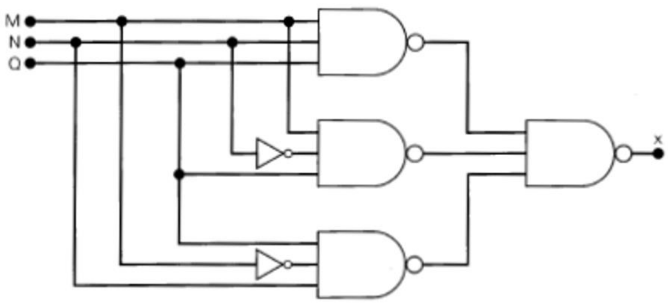
$$X = AB + A(\bar{B} + C) + AB\bar{C}$$

X=AB+AB'+AC+ABC'
= A(B+B')+AC+ABC'
= A+AC+ABC'
=A+ABC' = A

b) Repeat a) but this time using a K-map. (5 marks)

AB + AB' + AC + ABC'

c) Write the expression for the output x and simplify it using Boolean Algebra
(5 marks)

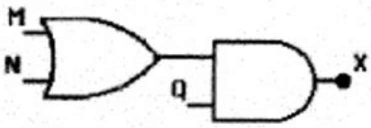


$$X = \overline{\overline{MNQ} \cdot \overline{M\bar{N}Q} \cdot \overline{\bar{M}NQ}}$$

$$X = MNQ + M\bar{N}Q + \bar{M}NQ$$

$$X = MQ + NQ$$

$$X = Q(M + N)$$



d) Simplify the following K-map and *write the resulting Boolean expression.* (5 marks)

	$\bar{C}\bar{D}$	$\bar{C}D$	CD	$C\bar{D}$
$\bar{A}\bar{B}$	1	0	1	1
$\bar{A}B$	0	0	0	1
AB	1	0	1	1
$A\bar{B}$	1	0	0	1

B'D'+CD'+AD'+ABC+A'B'C

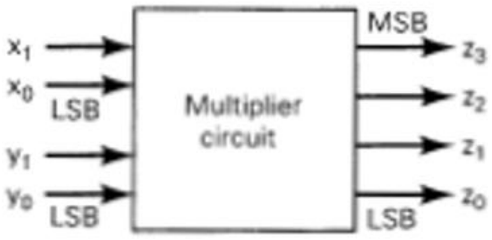
e) Simplify the following K-map and write the resulting Boolean expression. (5 marks)

	$\bar{C}\bar{D}$	$\bar{C}D$	CD	$C\bar{D}$
$\bar{A}\bar{B}$	1	0	1	1
$\bar{A}B$	1	0	x	0
AB	0	1	x	x
$A\bar{B}$	0	x	1	1

B'C+AD+A'C'D'

Question 3 – Logic Circuit Applications **(25 marks)**

Figure below shows a multiplier circuit that takes *two 2-bit binary numbers* x_1x_0 and y_1y_0, and produces an output binary number $z_3z_2z_1z_0$ that is equal to the **product of the input numbers**..



a) Produce a truth table for outputs z_3, z_2, z_1 and z_0. (10 marks)

x_1	x_0	y_1	y_0	z_3	z_2	z_1	z_0	
0	0	0	0	**0**	**0**	**0**	**0**	
0	0	0	1	**0**	**0**	**0**	**0**	
0	0	1	0	**0**	**0**	**0**	**0**	
0	0	1	1	**0**	**0**	**0**	**0**	
0	1	**0**	**0**	0	0	**0**	**0**	
0	1	**0**	**1**	0	0	**0**	**1**	
0	1	**1**	**0**	0	0	**1**	**0**	
0	1	**1**	**1**	0	0	**1**	**1**	
1	0	0	0	**0**	**0**	**0**	**0**	
1	0	0	1	**0**	**0**	**1**	**0**	*2*
1	0	1	0	**0**	**1**	**0**	**0**	*4*
1	0	1	1	**0**	**1**	**1**	**0**	*6*
1	1	0	0	**0**	**0**	**0**	**0**	
1	1	0	1	**0**	**0**	**1**	**1**	*3*
1	1	1	0	**0**	**1**	**1**	**0**	*6*
1	1	1	1	**1**	**0**	**0**	**1**	*9*

b) Write the SOP expressions for the outputs z_3, z_2, z_1 and z_0. (5 marks)

Z3=x1x0y1y0

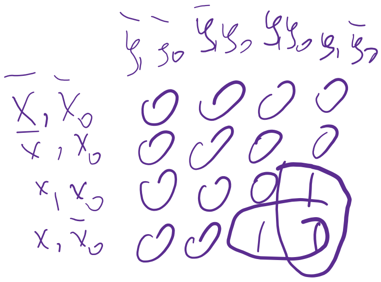
Z2=x1x0'y1y0' + x1x0'y1y0 + x1x0y1y0'

Z1= x1'x0y1y0'+ x1'x0y1y0+ x1x0'y1'y0+ x1x0'y1y0+ x1x0y1'y0+x1x0y1y0'

Z0= x1'x0y1'y0+ x1'x0y1y0+ x1x0y1'y0+ x1x0y1y0

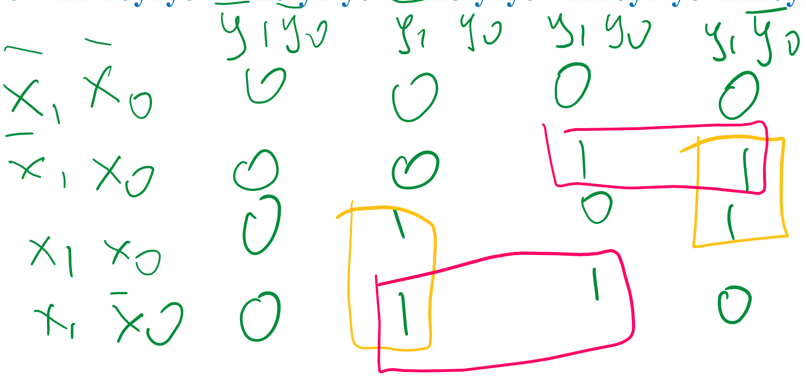
c) If needed, simplify the expressions for z_3, z_2, z_1, z_0. You don't have to use K-maps. (10 marks)

Z3=x1x0y1y0 nothing to simplify



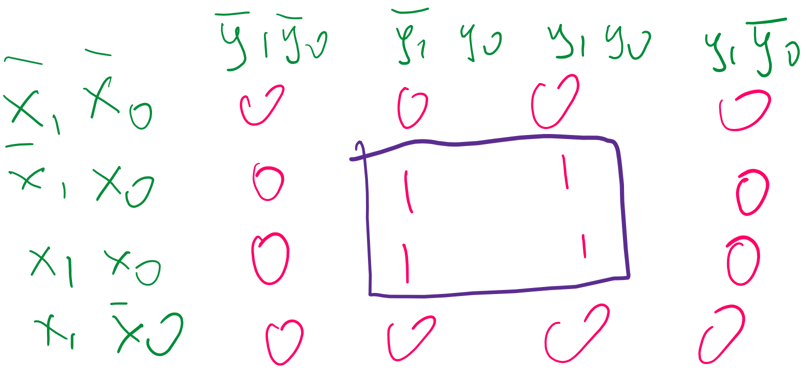
Z2=x1x0'y1y0' + x1x0'y1y0 + x1x0y1y0'
= x1x0'y1y0' + **x1x0'y1y0** + x1x0'y1y0' + **x1x0y1y0'**
= **x1x0'y1(y0' + y0) + x1y1y0'(x0+x0')**
= **x1x0'y1+x1y1y0'**

Z1= x1'x0y1y0'+ x1'x0y1y0+ x1x0'y1'y0+ x1x0'y1y0+ x1x0y1'y0+x1x0y1y0'



Z1= x1x0'y0+x1y1'y0+x1'x0y1+ x0y1y0'
= x1y0 (x0'+y1')+ x0y1 (x1'+ y0')

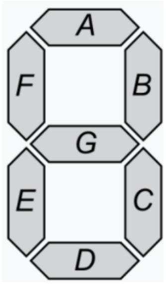
Z0= x1'x0y1'y0+ x1'x0y1y0+ x1x0y1'y0+ x1x0y1y0



Z0=x0y0

Question 4 – Logic Circuit Applications **25 marks**

We want to design a logic circuit for a 7-segment LED display shown below.



The inputs are 4 binary digits **d**, **c**, **b**, **a**, which represent the number to be displayed on the LED. Bit **d** is the most significant bit (MSB), and **a** is the least significant bit (LSB). Each LED segment (labelled A, B, C, … G on the diagram) has its own logic. For example, LED E is ON when **dcba** represent decimal numbers 0, 2, 6 or 8.

d) Produce a truth table to drive LED labelled **C.** **0 1 3 4 5 6 7 8 9** (6 marks)

d	**c**	**b**	**a**	**C**	
0	0	0	0	1	d’c’b’a’
0	0	0	1	1	d’c’b’a
0	**0**	**1**	**0**	**0**	
0	0	1	1	1	d’c’ba
0	1	0	0	1	d’cb’a’
0	1	0	1	1	d’cb’a
0	1	1	0	1	d’cba’
0	1	1	1	1	d’cba
1	0	0	0	1	dc’b’a’
1	0	0	1	1	da’b’a’
1	**0**	**1**	**0**	**X**	
1	0	1	1	**X**	
1	1	0	0	**X**	
1	1	0	1	**X**	
1	1	1	0	**X**	
1	1	1	1	**X**	

e) Write the sum-of-products (SOP) expression for C (4 marks)

C= d’c’b’a’ + d’c’b’a + d’c’ba + d’cb’a’ + d’cb’a + d’cba’ + d’cba + dc’b’a’ + da’b’a’

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f) Use a K-map to simplify the logic expression for C. (8 marks)

(Write your answer in the table provided below. Clearly mark the loop(s) of adjacent 1s.

	$\bar{b}\bar{a}$	$\bar{b}a$	ba	$b\bar{a}$
$\bar{d}\bar{c}$	1	1	1	0
$\bar{d}c$	1	1	1	1
dc	x	x	x	x
$d\bar{c}$	1	1	x	x

C = c+b'+a

It is tempting to solve for C' = d'c'ba' and invert using DeMorgan. This leads to C''=C=d+c+b'+a.

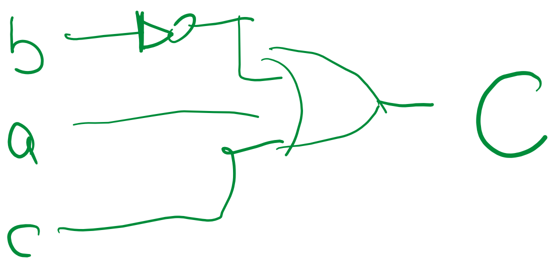
This is correct, but not as simple as possible.

Instead, we can include the first don't care condition:

C'=d'c'ba' + dc'ba' which gives C'=c'ba', which after inverting gives

C''=C=c+b'+a which is what we obtained using the K-Map

g) Draw a logic diagram for G using as **few gates as possible**. (7 marks)



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Fundamental Laws and Theorems of Boolean Algebra

1.	$X + 0 = X$	OR operations
2.	$X + 1 = 1$	
3.	$X + X = X$	
4.	$X + \overline{X} = 1$	
5.	$X . 0 = 0$	AND operations
6.	$X . 1 = X$	
7.	$X . X = X$	
8.	$X . \overline{X} = 0$	
9.	$\overline{\overline{X}} = X$	Double complement
10.	$X + Y = Y + X$	Commutative laws
11.	$XY = YX$	
12.	$(X + Y) + Z = X + (Y + Z)$	Associative laws
13.	$(X . Y). Z = X. (Y. Z)$	
14.	$X (Y + Z) = XY + XZ$	Distribution Law
15.	$X + Y .Z = (X + Y) . (X + Z)$	Dual of Distributive Law
16.	$X + XZ = X$	Laws of absorption
17.	$X (X + Z) = X$	
18.	$X + \overline{X} Y = X + Y$	Identity Theorems
19.	$X (\overline{X} + Y) = X.Y$	
20.	$\overline{X + Y} = \overline{X} . \overline{Y}$	De Morgan's Theorems
21.	$\overline{X.Y} = \overline{X} + \overline{Y}$	

Standard Logic Symbols

Used in lectures

Used in text book