10. Boolean Logic

Logic Gates

- Building block of a digital circuit: perform logical operations on one or more binary inputs to produce a binary output
- An electrical signal entering the logic gate is represented by a 1
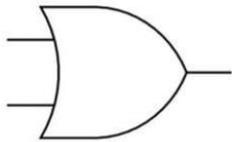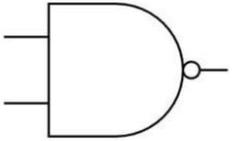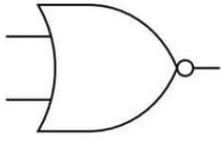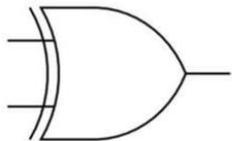- No electrical signal is represented by a 0

Gate	Symbol	Description
NOT		Takes a single binary input and outputs the opposite of the input
AND		Takes two inputs and produces one output (multiplication) - Only two positive inputs (1 and 1) will result in a positive output of 1 - If either of the inputs is a 0 the output will be a 0
OR		Takes two inputs and produces one output (addition) - If either of the inputs is positive (1), output will be 1
NAND		Combination of an AND gate followed by a NOT gate. - If both inputs are 1 it will output a 0. - Any other combination of inputs will result in an output of 1
NOR		Combination of an OR gate followed by a NOT gate. - If both inputs are 0 it will output a 1. - Any other combination of inputs will result in an output of 0
XOR/ EOR		(exclusive OR) will output a 1 if the inputs are different to one another (a 1 and a 0)
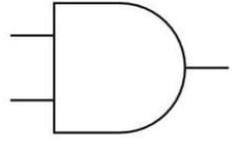
NOTE: NOT is a single input gate; all other gates are limited to 2 inputs.

Truth tables

NOT gate

Input	Output
A	Z
0	1
1	0

AND gate

Input		Output
A	B	Z
0	0	0
0	1	0
1	0	0
1	1	1

OR gate

Input		Output
A	B	Z
0	0	0
0	1	1
1	0	1
1	1	1

NOR gate

Input		Output
A	B	Z
0	0	1

0	1	0
1	0	0
1	1	0

NAND gate

Input		Output
A	B	Z
0	0	1
0	1	1
1	0	1
1	1	0

XOR gate

Input		Output
A	B	Z
0	0	0
0	1	1
1	0	1
1	1	0

- When creating a truth table for multiple inputs, begin by entering the possible input combinations into the leftmost columns

A	B	C		Z
0	0	0		
0	0	1		
0	1	0		
0	1	1		
1	0	0		

1	0	1		
1	1	0		
1	1	1		

- The column on the right contains the final output of the logic circuit (Z)
- Column(s) in between the inputs and the final output can be used to help work out the final output by containing intermediary outputs
- Intermediary outputs are the output of gates found within the logic circuit

Logic circuits

- Logic gates can be combined to produce different outputs.
- The combination of two or more logic gates forms a logic circuit.
- A logic diagram is a visual representation of combinations of logic gates within a logic circuit

Logic expressions

- A logic expression is a way of expressing a logic gate or logic circuit as an equation
- Output appears on the left of the equals sign with the inputs and logic gates on the right

Logic circuit:
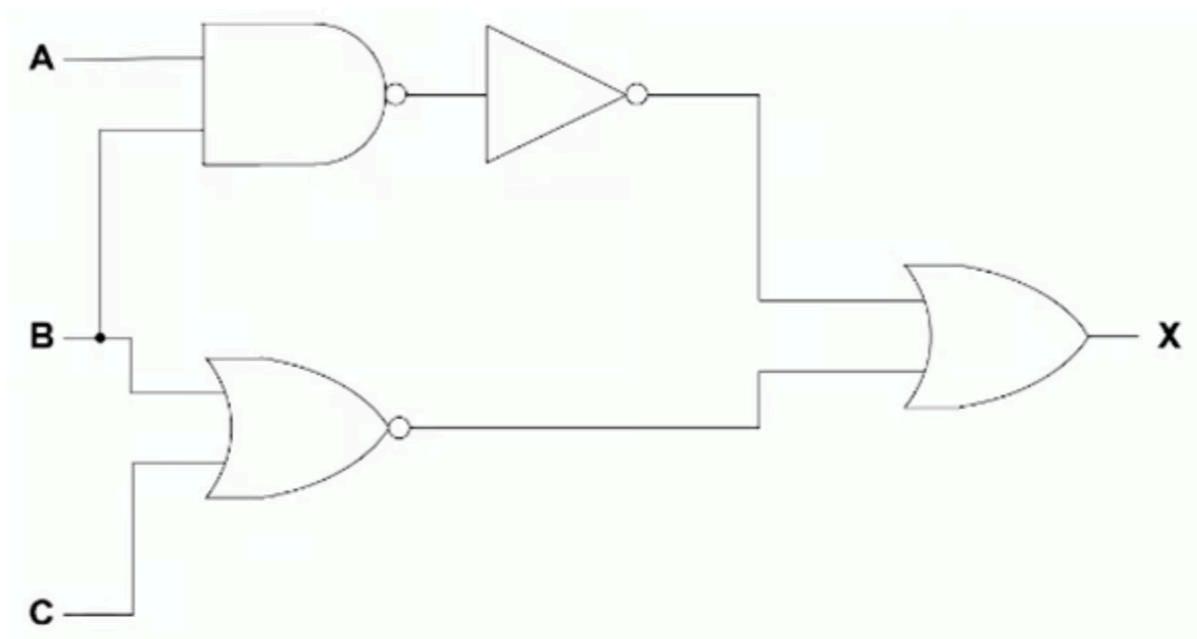
Logic expression: X= NOT(A NAND B) OR (B NOR C)

Exam questions

Question 1

7 Consider the truth table:

A	B	C	X
0	0	0	0
0	0	1	0
0	1	0	0
0	1	1	0
1	0	0	1
1	0	1	0
1	1	0	0
1	1	1	1

(a) Draw a logic circuit to represent the given truth table.

Each logic gate should have maximum of **two** inputs.

Do **not** simplify the logic circuit.

(b) Write a logic expression for the given truth table.
Do **not** simplify the logic expression.

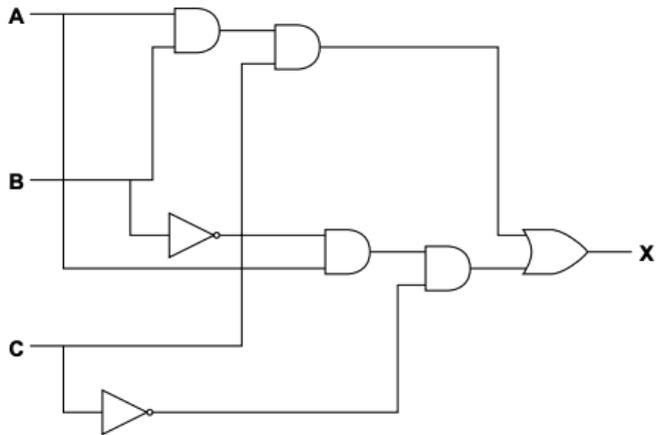..

....

....

....

....

....

....

.... [3]

One mark for each correct NOT gate and OR gate with correct direction of input(s),
three marks for four correct **AND** gates
or
two marks for three correct **AND** gates
or
one mark for two correct **AND** gates with correct direction of inputs:

X = ((A AND NOT B AND NOT C) OR (A AND B AND C))
One mark for each correct part of the logic expression:

(A AND NOT B AND NOT C)
OR
(A AND B AND C)