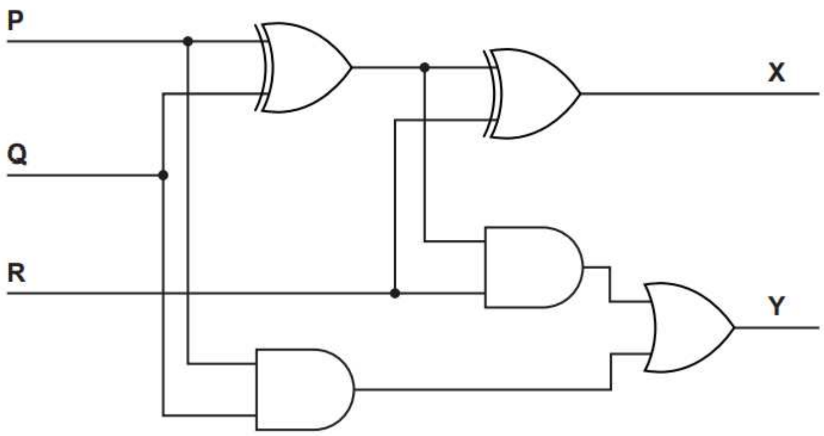
Logic Gates

Question 1

4 (a) Write the Boolean algebraic expressions for the following logic circuit.



X = ...

....

Y = ...

....
[5]

(b) The logic circuit given in **part (a)** is a full adder.

(i) Give the purpose of outputs **X** and **Y** in this circuit.

X ....

Y ....
[2]

(ii) Give the use of the input **R** in this circuit.

.... [1]

Question 2

4 The following truth table represents a logic circuit with three inputs and two outputs.

INPUT			OUTPUT	
A	**B**	**C**	**X**	**Y**
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

(a) Write the Boolean expressions for the truth table as sum-of-products.

X = ...

....

Y = ...

....
[4]

(b) Complete the Karnaugh Maps (K-maps) for the truth table.

OUTPUT X
AB

		00	**01**	**11**	**10**
C	**0**				
	1				

OUTPUT Y
AB

		00	**01**	**11**	**10**
C	**0**				
	1				

[2]

(c) The K-maps can be used to simplify **one** of the expressions in **part (a)**.

(i) Draw loop(s) around appropriate group(s) of 1s to produce an optimal sum-of-products for the single output table that can be simplified in **part (b)**. [3]

(ii) Write the simplified sum-of-products expressions for this output from **part (c)(i)**.

.... [3]

(d) Identify the common logic circuit given by the truth table in **part (a)**. Give the use of each output.

Logic circuit ....

Use of **X** ....

Use of **Y** ....
[3]

Question 3

4 The following truth table represents a logic circuit with three inputs and two outputs.

INPUT			OUTPUT	
A	**B**	**C**	**X**	**Y**
0	0	0	1	0
0	0	1	0	0
0	1	0	0	0
0	1	1	0	1
1	0	0	0	0
1	0	1	0	1
1	1	0	0	0
1	1	1	1	1

(a) Write the Boolean expressions for the truth table as sum-of-products.

X = ...

Y = ...
[3]

(b) Complete the Karnaugh Maps (K-maps) for the truth table.

OUTPUT X

		AB			
		00	**01**	**11**	**10**
C	**0**				
	1				

OUTPUT Y

		AB			
		00	**01**	**11**	**10**
C	**0**				
	1				

[2]

(c) The K-maps can be used to simplify **one** of the expressions in **part (a)**.

(i) Draw loop(s) around appropriate group(s) of 1s to produce an optimal sum-of-products for the single output table that can be simplified in **part (b)**. [2]

(ii) Write the simplified sum-of-products expressions for this output from **part (c)(i)**.

.... [2]

Question 4

5 Complete these statements about flip-flops.

A flip-flop is a ....

It has .... stable states.

A flip-flop is used for ....

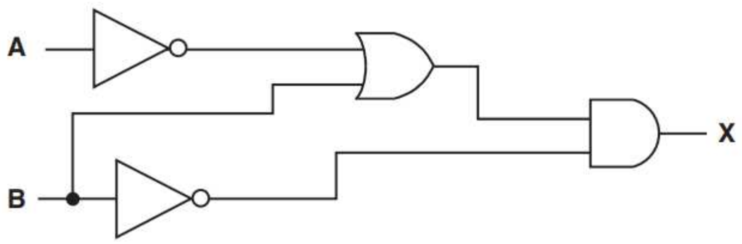
There are different types of flip-flop, for example .... and

....

[5]

Question 5

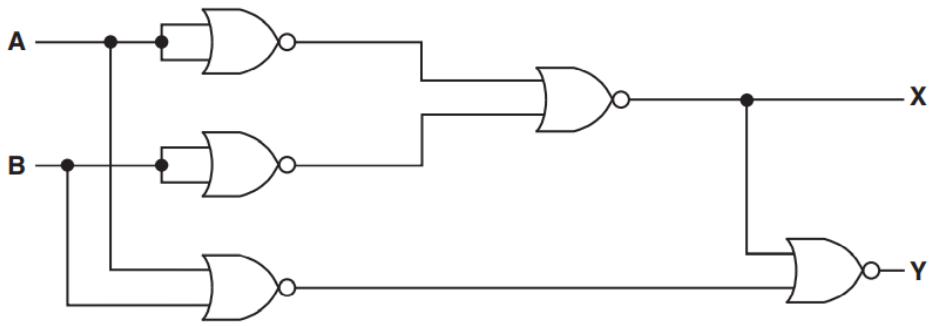
3 (a) The following logic circuit can be simplified to use only one gate.



Give the name of this single gate.

.... [1]

(b) (i) Complete the truth table for the logic circuit.



A	B	Working space	X	Y
0	0			
0	1			
1	0			
1	1			

[2]

(ii) Give the name of the logic circuit that has this truth table.

.... [1]

(iii) Give the uses for outputs **X** and **Y**.

X ....

Y ....

[2]

(c) Consider the following Boolean algebraic expression:

$$\overline{A} . \overline{B} . \overline{C} . \overline{D} + \overline{A} . \overline{B} . \overline{C} . D + \overline{A} . \overline{B} . C . D + \overline{A} . \overline{B} . C . \overline{D} + \overline{A} . B . \overline{C} . \overline{D}$$

Use Boolean algebra to simplify the expression. Show your working.

Working ....

....

....

....

....

....

....

....

....

Simplified expression .... [5]

Question 6

3 **(a)** A Boolean algebraic expression produces the following truth table.

INPUT			OUTPUT
A	**B**	**C**	**X**
0	0	0	1
0	0	1	1
0	1	0	1
0	1	1	1
1	0	0	1
1	0	1	1
1	1	0	0
1	1	1	0

(i) Complete the Karnaugh Map (K-map) for the truth table.

		AB			
		00	**01**	**11**	**10**
C	**0**				
	1				

[1]

The K-map can be used to simplify the expression that produced the truth table in **part (a)**.

(ii) Draw loops around appropriate groups of 1s in the K-map to produce an optimal sum-of-products. [2]

(iii) Write the simplified sum-of-products Boolean expression for the truth table.

X = ... [2]

(b) A logic circuit with four inputs produces the following truth table.

INPUT				OUTPUT
A	**B**	**C**	**D**	**X**
0	0	0	0	0
0	0	0	1	0
0	0	1	0	1
0	0	1	1	1
0	1	0	0	0
0	1	0	1	0
0	1	1	0	1
0	1	1	1	1
1	0	0	0	1
1	0	0	1	1
1	0	1	0	0
1	0	1	1	0
1	1	0	0	1
1	1	0	1	1
1	1	1	0	0
1	1	1	1	0

(i) Complete the K-map for the truth table.

		AB			
CD					

[4]

(ii) Draw loops around appropriate groups of 1s in the K-map to produce an optimal sum-of-products. [2]

(iii) Write the simplified sum-of-products Boolean algebraic expression for the truth table.

X = ... [2]

Question 7

4 A Boolean expression produces the following truth table.

INPUT			OUTPUT
A	**B**	**C**	**X**
0	0	0	1
0	0	1	1
0	1	0	0
0	1	1	1
1	0	0	0
1	0	1	1
1	1	0	0
1	1	1	1

(a) Write the Boolean expression for the truth table as a sum-of-products.

X = ... [2]

(b) Complete the Karnaugh Map (K-map) for the truth table above.

AB

		00	**01**	**11**	**10**
C	**0**				
	1				

[1]

The K-map can be used to simplify the expression in **part (a)**.

(c) Draw loops around appropriate groups in the K-map in **part (b)** to produce an optimal sum-of-products. [2]

(d) Write, using your answer to **part (c)**, a simplified sum-of-products expression for the truth table.

X = ... [2]

Question 8

2 **(a)** A Boolean expression produces the following truth table.

INPUT			**OUTPUT**
A	**B**	**C**	**X**
0	0	0	1
0	0	1	1
0	1	0	1
0	1	1	1
1	0	0	1
1	0	1	1
1	1	0	0
1	1	1	0

(i) Write the Boolean expression for the truth table by applying the sum-of-products.

X = ...

.... [3]

(ii) Complete the Karnaugh Map (K-map) for the truth table in **part (a)**.

		AB			
		00	**01**	**11**	**10**
C	**0**				
	1				

[1]

The K-map can be used to simplify the function in **part (a)(i)**.

(iii) Draw loop(s) around appropriate groups in the table in **part (a)(ii)**, to produce an optimal sum-of-products. [2]

(iv) Write, using your answer to **part (a)(iii)**, a simplified Boolean expression for your Karnaugh map.

X = ... [2]

(b) Simplify the following expression using De Morgan's laws. Show your working.

$$(\overline{\overline{W} + X) \bullet (Y + \overline{Z}})$$

....

....

....

....

....

.... [3]

Question 9

4 **(a)** A Boolean expression produces the following truth table.

INPUT			OUTPUT
A	**B**	**C**	**X**
0	0	0	0
0	0	1	0
0	1	0	1
0	1	1	1
1	0	0	1
1	0	1	1
1	1	0	0
1	1	1	0

(i) Write the Boolean expression for the truth table as a sum-of-products.

X = ...[2]

(ii) Complete the Karnaugh Map (K-map) for the truth table in **part (a)(i)**.

AB

		00	**01**	**11**	**10**
C	**0**				
	1				

[1]

The K-map can be used to simplify the function in **part (a)(i)**.

(iii) Draw loop(s) around appropriate group(s) of 1s to produce an optimal sum-of-products for the table in **part (a)(ii)**. [2]

(iv) Write the simplified sum-of-products expression for your answer to **part (a)(iii)**.

X = ...[2]

(b) A logic circuit with four inputs produces the following truth table.

INPUT				OUTPUT
A	**B**	**C**	**D**	**X**
0	0	0	0	0
0	0	0	1	0
0	0	1	0	0
0	0	1	1	0
0	1	0	0	1
0	1	0	1	1
0	1	1	0	1
0	1	1	1	1
1	0	0	0	0
1	0	0	1	0
1	0	1	0	0
1	0	1	1	0
1	1	0	0	1
1	1	0	1	1
1	1	1	0	0
1	1	1	1	0

(i) Complete the K-map that corresponds to the truth table.

AB

CD

[4]

(ii) Draw loop(s) around appropriate group(s) of 1s to produce an optimal sum-of-products for the table in **part (b)(i)**. [2]

(iii) Write the simplified sum-of-products expression for your answer to **part (b)(ii)**.

X = ...[2]

Question 10

4 **(a)** A Boolean expression corresponds to the following truth table.

INPUT			OUTPUT
A	**B**	**C**	**X**
0	0	0	0
0	0	1	0
0	1	0	0
0	1	1	1
1	0	0	0
1	0	1	1
1	1	0	1
1	1	1	1

(i) Write the Boolean expression for the truth table by applying the sum-of-products.

X = ... [2]

(ii) Complete the Karnaugh Map (K-map) for the truth table.

		AB			
		00	**01**	**11**	**10**
C	**0**				
	1				

[1]

(iii) The K-map can be used to simplify the expression in **part (a)(i)**.

Draw loop(s) around appropriate groups of 1s in the table in **part (a)(ii)** to produce an optimal sum-of-products. [3]

(iv) Write the simplified sum-of-products expression for your answer to **part (a)(iii)**.

X = ... [3]

(b) A logic circuit with four inputs produces the following truth table.

INPUT				OUTPUT
A	**B**	**C**	**D**	**X**
0	0	0	0	0
0	0	0	1	0
0	0	1	0	0
0	0	1	1	0
0	1	0	0	1
0	1	0	1	0
0	1	1	0	0
0	1	1	1	0
1	0	0	0	0
1	0	0	1	0
1	0	1	0	0
1	0	1	1	0
1	1	0	0	1
1	1	0	1	1
1	1	1	0	1
1	1	1	1	1

(i) Complete the K-map that corresponds to the truth table.

AB

CD				

[4]

(ii) Draw loop(s) around appropriate groups of 1s in the table in **part (b)(i)** to produce an optimal sum-of-products. [2]

(iii) Write the simplified sum-of-products expression for your answer to **part (b)(ii)**.

X = ...[2]

Question 11

3 **(a)** Consider the following Boolean expression.

$$A . \overline{B} . \overline{C} + A . B . \overline{C} + A . B . C$$

Use Boolean algebra to simplify the expression.

....

....

....

....

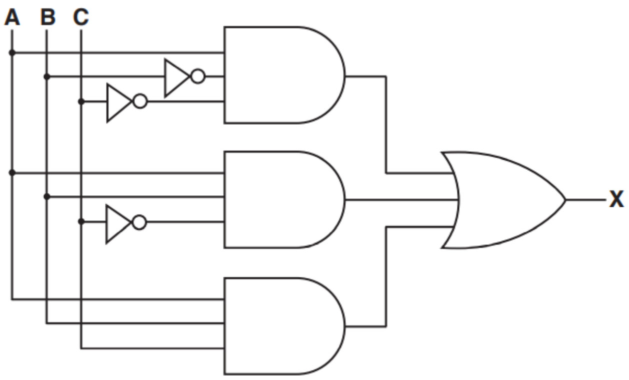
....

....

....

....[4]

(b) **(i)** Complete the truth table for the following logic circuit.



A	B	C	Working space	X
0	0	0		
0	0	1		
0	1	0		
0	1	1		
1	0	0		
1	0	1		
1	1	0		
1	1	1		

[2]

(ii) Complete the Karnaugh Map (K-map) for the truth table in **part (b)(i)**.

		AB			
		00	01	11	10
C	0				
	1				

[1]

(iii) Draw loops around appropriate groups of 1s in the table in **part (b)(ii)** to produce an optimal sum-of-products. [2]

(iv) Using your answer to **part (b)(iii)**, write a simplified sum-of-products Boolean expression.

X = ...[2]

(c) The truth table for a logic circuit with four inputs is shown.

INPUT				OUTPUT
A	**B**	**C**	**D**	**X**
0	0	0	0	0
0	0	0	1	0
0	0	1	0	0
0	0	1	1	0
0	1	0	0	1
0	1	0	1	0
0	1	1	0	0
0	1	1	1	0
1	0	0	0	0
1	0	0	1	0
1	0	1	0	0
1	0	1	1	0
1	1	0	0	1
1	1	0	1	1
1	1	1	0	1
1	1	1	1	1

(i) Complete the K-map for the truth table in **part (c)**.

AB

CD

[4]

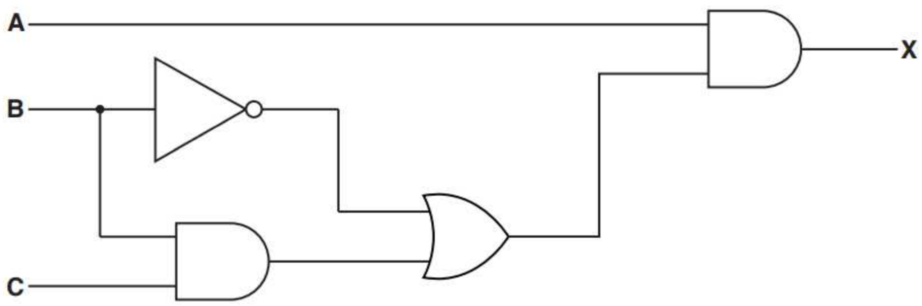
(ii) Draw loops around appropriate groups of 1s in the table in **part (c)(i)** to produce an optimal sum-of-products. [2]

(iii) Using your answer to **part (c)(ii)**, write a simplified sum-of-products Boolean expression.

X = ...[2]

Question 12

3 Consider the following logic circuit, which contains a redundant logic gate.



(a) Write the Boolean algebraic expression corresponding to this logic circuit.

X = ...[3]

(b) Complete the truth table for this logic circuit.

A	B	C	Working space	X
0	0	0		
0	0	1		
0	1	0		
0	1	1		
1	0	0		
1	0	1		
1	1	0		
1	1	1		

[2]

(c) **(i)** Complete the Karnaugh Map (K-map) for the truth table in **part (b)**.

		AB			
		00	**01**	**11**	**10**
C	**0**				
	1				

[1]

The K-map can be used to simplify the expression in **part (a)**.

(ii) Draw loop(s) around appropriate groups to produce an optimal sum-of-products. [2]

(iii) Write a simplified sum-of-products expression, using your answer to **part (ii)**.

X = ...[2]

(d) One Boolean identity is:

$$A + \overline{A}.B = A + B$$

Simplify the expression for X in **part (a)** to the expression for X in **part (c)(iii)**. You should use the given identity.

....

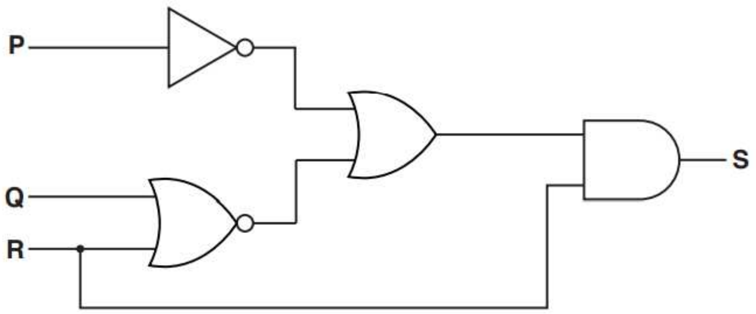
....

....

....[2]

Question 13

3 A logic circuit is shown:



(a) Write the Boolean algebraic expression corresponding to this logic circuit:

S = ...[4]

(b) Complete the truth table for this logic circuit:

P	Q	R	Working space	S
0	0	0		
0	0	1		
0	1	0		
0	1	1		
1	0	0		
1	0	1		
1	1	0		
1	1	1		

[2]

(c) **(i)** Complete the Karnaugh Map (K-map) for the truth table in **part (b)**.

		PQ			
		00	**01**	**11**	**10**
R	**0**				
	1				

[1]

The K-map can be used to simplify the function in **part (a)**.

(ii) Draw loop(s) around appropriate groups to produce an optimal sum-of-products. [1]

(iii) Write a simplified sum-of-products expression, using your answer to **part (ii)**.

S = ...[1]

(d) One Boolean identity is:

$$(A + B) . C = A . C + B . C$$

Simplify the expression for S in **part (a)** to the expression for S in **part (c)(iii)**.

You should use the given identity and De Morgan's Laws.

....

....

....

....

....

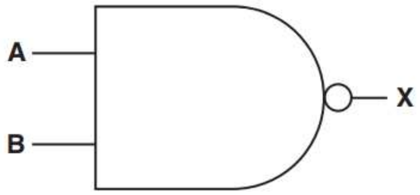
....

....

....[3]

Question 14

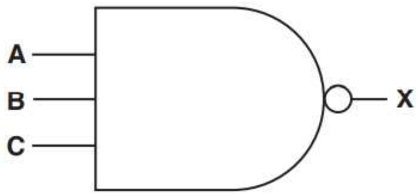
5 (a) (i) Complete the truth table for this 2-input NAND gate:



A	B	X
0	0	
0	1	
1	0	
1	1	

[1]

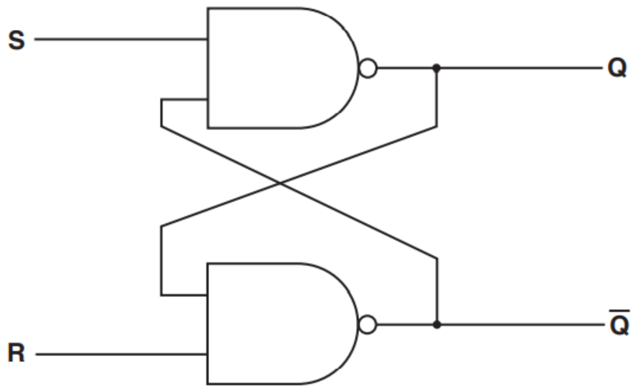
(ii) Complete the truth table for this 3-input NAND gate:



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

[1]

(b) A SR flip-flop is constructed using two NAND gates.



(i) Complete the truth table for the SR flip-flop:

	S	R	Q	$\overline{Q}$
Initially	1	0	0	1
R changed to 1	1	1		
S changed to 0	0	1		
S changed to 1	1	1		
S and R changed to 0	0	0	1	1

[3]

(ii) The final row in the table in **part b(i)** shows that the output for both **Q** and **$\overline{\mathbf{Q}}$** is 1.

Explain why this is a problem.

....

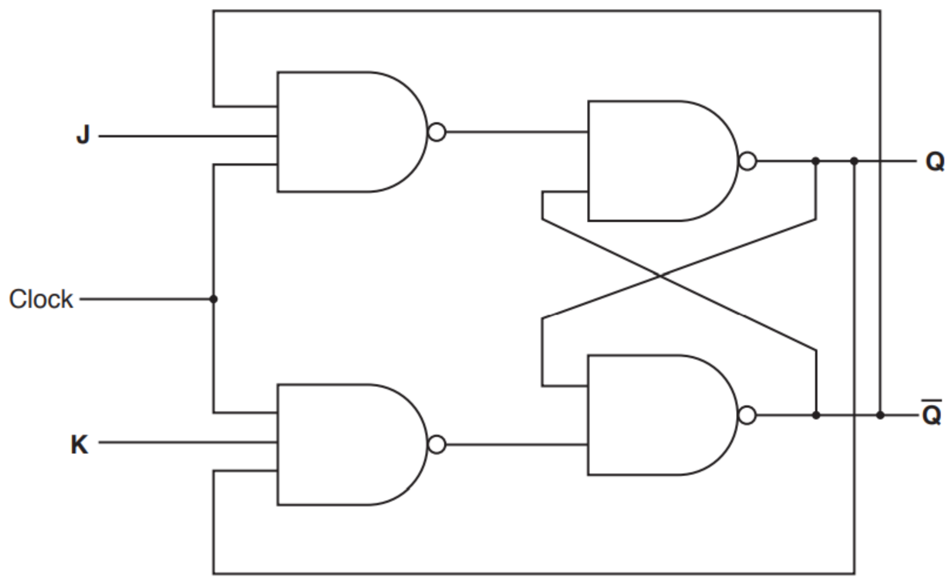
....

....

.... [2]

(c) Another type of flip-flop is the JK flip-flop.

A JK flip-flop is constructed as follows:



(i) Complete this truth table for the JK flip-flop.

J	K	Clock	Working space	Initial values Q	Initial values $\overline{Q}$	Final values Q	Final values $\overline{Q}$
0	0	1		1	0	1	0
0	0	1		0	1	0	1
0	1	1		1	0	0	1
0	1	1		0	1	0	1
1	0	1		1	0		
1	0	1		0	1		
1	1	1		1	0		
1	1	1		0	1		

[4]

(ii) Explain why the JK flip-flop is an improvement on the SR flip-flop.

....

....

....

.... [2]

(d) Explain the role of flip-flops in a computer.

....

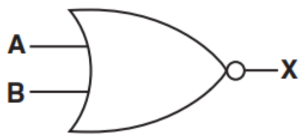
....

....

.... [2]

Question 15

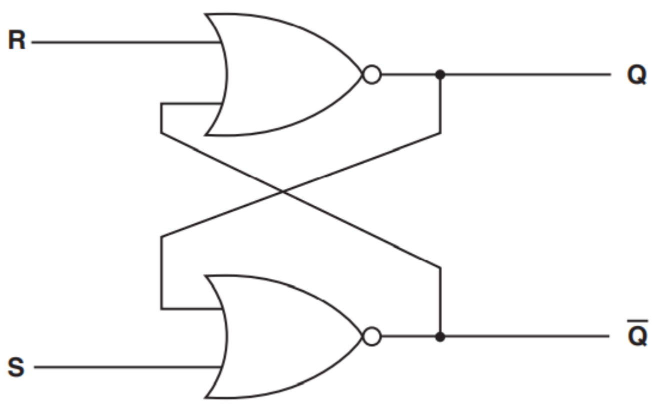
5 (a) Complete the truth table for this NOR gate:



A	B	X
0	0	
0	1	
1	0	
1	1	

[1]

A SR flip-flop is constructed using two NOR gates.



(b) Complete the truth table for the SR flip-flop:

	S	**R**	**Q**	$\overline{\textbf{Q}}$
Initially	1	0	1	0
S changed to 0	0	0		
R changed to 1	0	1		
R changed to 0	0	0		
S and R changed to 1	1	1		

[4]

Another type of flip-flop is the JK flip-flop. The JK flip-flop is an improvement on the SR flip-flop.

(c) **(i)** The JK flip-flop has three inputs. Two of the inputs are the Set (J) and the Reset (K).

State the third input.

....[1]

(ii) There are **two** problems with the SR flip-flop that the JK flip-flop overcomes.

State each problem and state why it does not occur for the JK flip-flop.

Problem 1 ....

....

....

....

Problem 2 ....

....

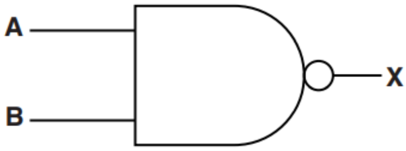
....

....

[4]

Question 16

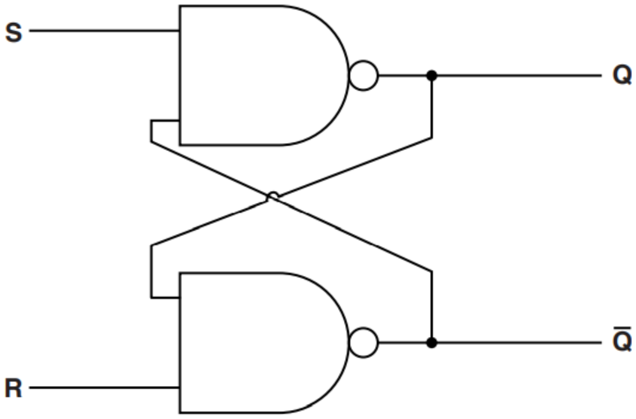
5 **(a)** Complete the truth table for this NAND gate:



A	B	X
0	0	
0	1	
1	0	
1	1	

[1]

A SR flip-flop is constructed using two NAND gates.



(b) **(i)** Complete the truth table for the SR flip-flop.

	S	R	Q	$\bar{Q}$
Initially	1	0	0	1
R changed to 1	1	1		
S changed to 0	0	1		
S changed to 1	1	1		
S and R changed to 0	0	0		

[4]

(ii) One of the combinations in the truth table should not be allowed to occur.

State the values of S and R that should not be allowed. Justify your choice.

S = ... R = ...

....

....

....

....[3]

Another type of flip-flop is the JK flip-flop.

(c) **(i)** Give one extra input present in the JK flip-flop.

....

....[1]

(ii) Give **one** advantage of the JK flip-flop.

....

....[1]

(d) Describe the role of flip-flops in a computer.

....

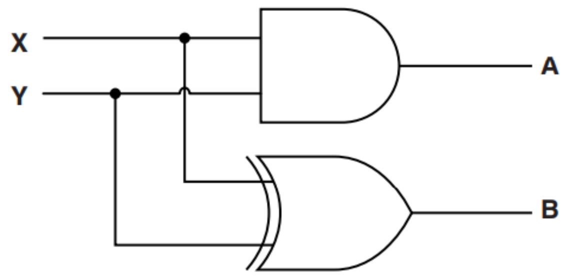
....

....

....[2]

Question 17

4 **(a)** **(i)** Complete the truth table for this logic circuit.



Input		Output	
X	**Y**	**A**	**B**
0	0		
0	1		
1	0		
1	1		

[2]

(ii) State the name given to this logic circuit.

.... [1]

(iii) Name the labels usually given to **A** and **B**.

Label **A** ....

Label **B** ....

Explain why your answers are more appropriate for the **A** and **B** labels.

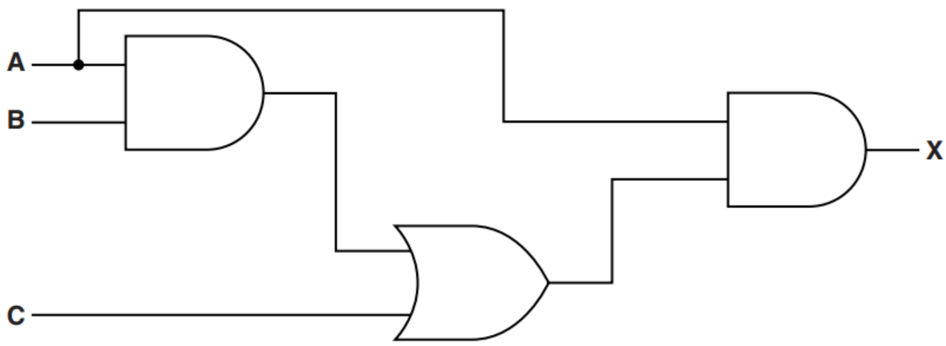
....

....

....

.... [4]

(b) (i) Write the Boolean expression corresponding to the following logic circuit:



.... [2]

(ii) Use Boolean algebra to simplify the expression that you gave in **part (b)(i)**.

Show your working.

....

....

....

....

....

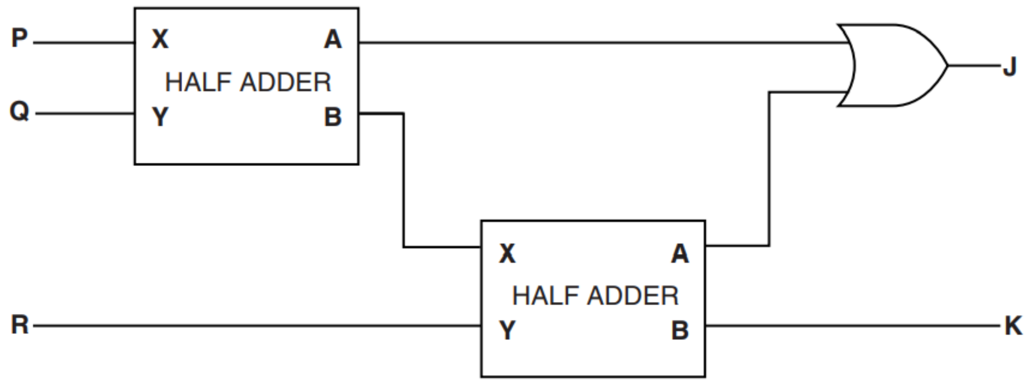
.... [3]

Question 18

5 **(a)** **(i)** A half adder is a logic circuit with the following truth table.

Input		**Output**	
X	**Y**	**A**	**B**
0	0	0	0
0	1	0	1
1	0	0	1
1	1	1	0

The following logic circuit is constructed.



Complete the following truth table for this logic circuit.

Input			**Working space**	**Output**	
P	**Q**	**R**		**J**	**K**
0	0	0			
0	0	1			
0	1	0			
0	1	1			
1	0	0			
1	0	1			
1	1	0			
1	1	1			

[2]

(ii) State the name given to this logic circuit.

.... [1]

(iii) Name the labels usually given to **J** and **K**.

Label **J** ....

Label **K** ....

Explain why your answers are appropriate labels for these outputs.

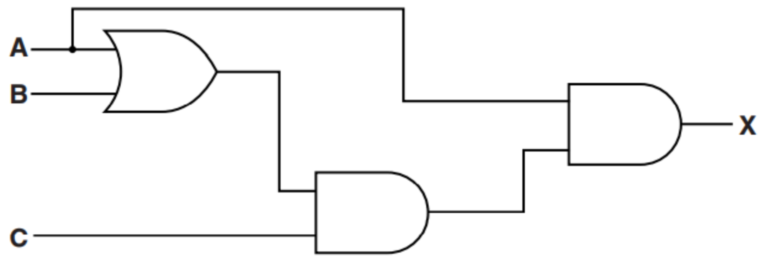
....

....

....

.... [4]

(b) **(i)** Write down the Boolean expression corresponding to the following logic circuit:



.... [2]

(ii) Use Boolean algebra to simplify the expression given in **part (b)(i)**.

Show your working.

....

....

....

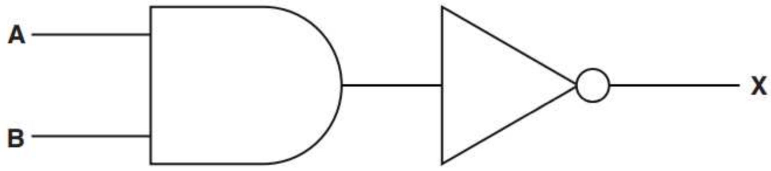
....

....

.... [4]

Question 19

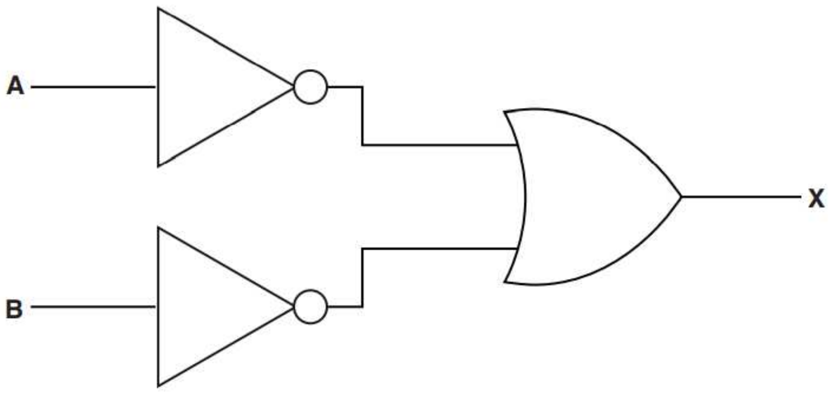
4 **(a)** **(i)** Complete the truth table for this logic circuit:



A	B	Working space	X
0	0		
0	1		
1	0		
1	1		

[1]

(ii) Complete the truth table for this logic circuit:



A	B	Working space	X
0	0		
0	1		
1	0		
1	1		

[1]

(b) A student decides to write an equation for **X** to represent the full behaviour of each logic circuit.

(i) Write the Boolean expression that will complete the required equation for **X** for each circuit:

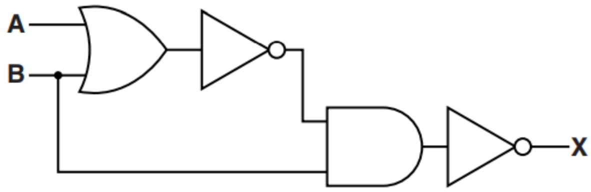
Circuit 1: **X** = ...

Circuit 2: **X** = ...[2]

(ii) Write the De Morgan's Law which is shown by your answers to **part (a)** and **part (b)(i)**.

....[1]

(c) Write the Boolean algebraic expression corresponding to the following logic circuit:



....[3]

(d) Using De Morgan's laws and Boolean algebra, simplify your answer to **part (c)**.

Show all your working.

....

....

....

....

....

....[3]

Question 20

5 **(a)** **(i)** Complete the Boolean function that corresponds to the following truth table.

INPUT			OUTPUT
A	**B**	**C**	**X**
0	0	0	0
0	0	1	0
0	1	0	0
0	1	1	1
1	0	0	0
1	0	1	0
1	1	0	1
1	1	1	1

$X = \overline{A} . B . C +$ ....[3]

The part to the right of the equals sign is known as the sum-of-products.

(ii) For the truth table above complete the Karnaugh Map (K-map).

		AB			
		00	**01**	**11**	**10**
C	**0**				
	1				

[1]

The K-map can be used to simplify the function in **part(a)(i)**.

(iii) Draw loop(s) around appropriate groups of 1's to produce an optimal sum-of-products. [2]

(iv) Using your answer to **part (a)(iii)**, write the simplified sum-of-products Boolean function.

X = ...[2]

(b) The truth table for a logic circuit with four inputs is given below:

INPUT				OUTPUT
A	**B**	**C**	**D**	**X**
0	0	0	0	0
0	0	0	1	0
0	0	1	0	0
0	0	1	1	0
0	1	0	0	1
0	1	0	1	0
0	1	1	0	1
0	1	1	1	0
1	0	0	0	0
1	0	0	1	0
1	0	1	0	0
1	0	1	1	0
1	1	0	0	1
1	1	0	1	0
1	1	1	0	1
1	1	1	1	1

(i) Complete the K-map corresponding to the truth table above.

AB

CD

[4]

(ii) Draw loop(s) around appropriate groups of 1's to produce an optimal sum-of-products. [2]

(iii) Using your answer to **part (b)(ii)**, write the simplified sum-of-products Boolean function.

X = ...[2]

Question 21

5 **(a)** **(i)** Complete the Boolean function that corresponds to the following truth table.

INPUT			**OUTPUT**
P	**Q**	**R**	**Z**
0	0	0	0
0	0	1	0
0	1	0	0
0	1	1	0
1	0	0	1
1	0	1	1
1	1	0	0
1	1	1	1

$Z = P \,.\, \overline{Q} \,.\, \overline{R} +$ ....[3]

The part to the right of the equals sign is known as the sum-of-products.

(ii) For the truth table above complete the Karnaugh Map (K-map).

		PQ			
		00	**01**	**11**	**10**
R	**0**				
	1				

[1]

The K-map can be used to simplify the function in **part(a)(i)**.

(iii) Draw loop(s) around appropriate groups of 1's to produce an optimal sum-of-products. [2]

(iv) Using your answer to **part (a)(iii)**, write the simplified sum-of-products Boolean function.

Z = ...[1]

(b) The truth table for a logic circuit with four inputs is given below:

INPUT				OUTPUT
P	**Q**	**R**	**S**	**Z**
0	0	0	0	0
0	0	0	1	0
0	0	1	0	0
0	0	1	1	0
0	1	0	0	0
0	1	0	1	1
0	1	1	0	0
0	1	1	1	1
1	0	0	0	0
1	0	0	1	1
1	0	1	0	0
1	0	1	1	0
1	1	0	0	0
1	1	0	1	1
1	1	1	0	0
1	1	1	1	1

(i) Complete the K-map corresponding to the truth table above.

PQ

RS

[4]

(ii) Draw loop(s) around appropriate groups of 1's to produce an optimal sum-of-products. [2]

(iii) Using your answer to **part (b)(ii)**, write the simplified sum-of-products Boolean function.

Z = ...[2]