Unit 8: Boolean Algebra
(A Level Only Content)

Marks: /36

Answer **all** the questions.

1. A half adder has the truth table shown below:

A	B	Sum	Carry
1	1	0	1
1	0	1	0
0	1	1	0
0	0	0	0

Draw a half adder using logic gates.

[3]

2(a). A cinema offers discounted tickets, but only under one of the following conditions:

- Customer is under 18 and has a student card.
- Customer is over 60 and has ID which proves this.

Let:

A be Customer is under 18

B be Customer has a student card

C be Customer is over 60

D be Customer has ID

Q be Discount ticket issued

Complete the Boolean expression below:

$Q \equiv$ _____ [3]

(b). The cinema has a voucher which promises free popcorn when the voucher is produced whilst buying a soft drink or bottle of water.

Let:

E be Voucher is shown

F be Soft drink is bought

G be Bottle of water is bought

R be Free popcorn given.

This could be written as:

$$R \equiv (E \wedge F) \vee (E \wedge G)$$

(i) Complete the truth table below.

E	F	G	(E∧F)	(E∧G)	(E∧F)∨(E∧G)
1	1	1			
1	1	0			
1	0	1			
1	0	0			
0	1	1			
0	1	0			
0	0	1			
0	0	0			

[4]

(ii) Simplify the expression

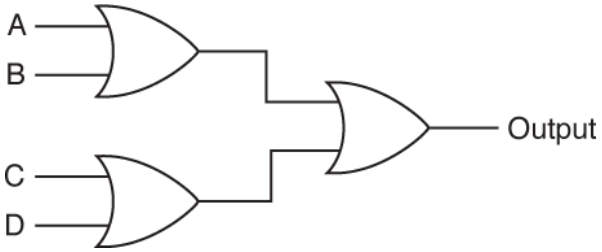
$(E \wedge F) \vee (E \wedge G)$

---

[2]

3.

A circuit contains the logic gates shown below.



(i) Complete the logic table below.

A	B	C	D	Output
1	1	1	1	
1	1	1	0	
1	1	0	1	
1	1	0	0	
1	0	1	1	
1	0	1	0	
1	0	0	1	
1	0	0	0	
0	1	1	1	
0	1	1	0	
0	1	0	1	
0	1	0	0	
0	0	1	1	
0	0	1	0	
0	0	0	1	
0	0	0	0	

[4]

(ii) Complete the Boolean expression below to represent the circuit.

---------- ≡ Output

[2]

4(a). The component below is a D-Type, positive edge triggered, flip-flop.

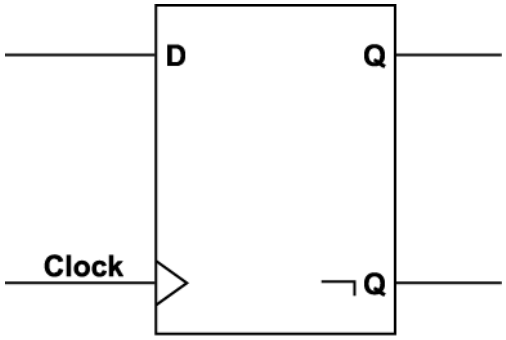


Fig. 10.2

State the purpose of a flip-flop.

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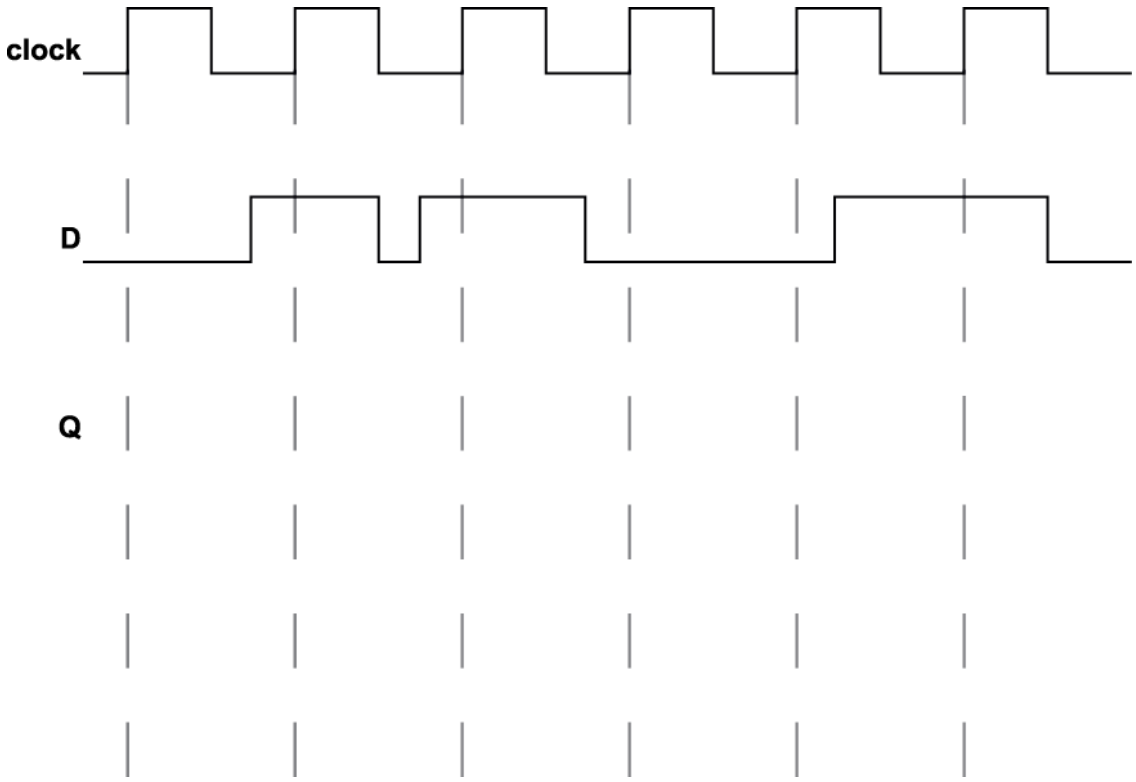
[1]

(b). Draw the output of the flip-flop from Fig. 10.2 on the diagram below.



[3]

5. State the simplified versions of the following Boolean expressions:

(i) ¬ ¬A

---

[1]

(ii) (¬A ∧ ¬B)

---

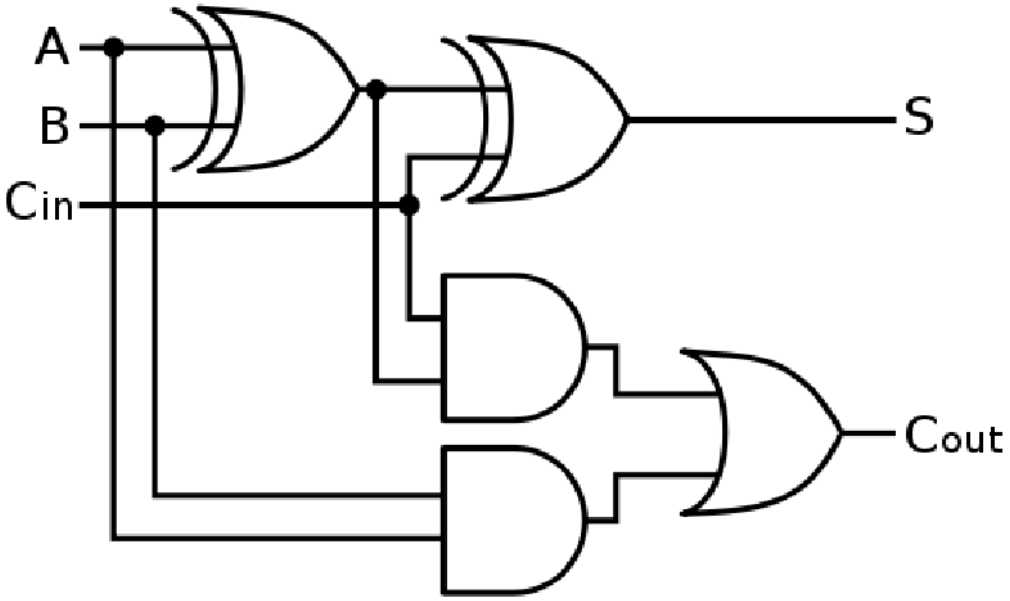
[1]

(iii) ¬(¬A ∧ ¬B)

---

[1]

6(a). A set of logic gates are connected as below.



(i) Complete the Truth Table below:

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

[4]

(ii) Explain what the circuit does. You should refer to A, B, C_{in}, S and C_{out} in your answer.

---

[4]

(b).

(i) Write a Boolean expression equivalent to S.

$S \equiv$

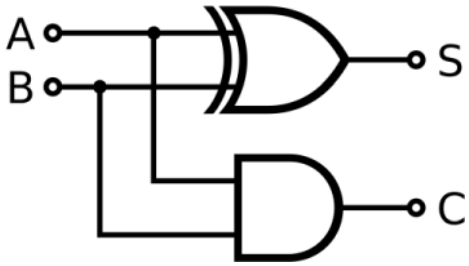
[1]

(ii) Write a Boolean expression equivalent to C_{out}.

$C_{out} \equiv$

[2]

END OF QUESTION PAPER

Question			Answer/Indicative content	Marks	Guidance
1			 XOR Gate (1) AND Gate (1) Correct connections and no additional gates (1)	3 (AO1,1)	**Examiner's Comments** Most candidates scored well on these questions demonstrating their understanding of logic gate circuits. Some candidates simplified the circuit in part b) which achieved full marks provided the resultant circuit gave the same output.
			Total	**3**	
2	a		Q = (A∧B) ∨ (C∧D) 1 mark for (A∧B) 1 mark for (C∧D) 1 mark for the ∨ joining the two parts.	3 (AO1.2)	Accept (C∧D) ∨ (A∧B) Accept (B∧A) instead of (A∧B) Accept (D∧C) instead of (C∧D) Accept alternative notations (e.g. +/. OR / AND) Accept AB as (A.B) and CD as (C.D) Accept answers without brackets **Examiner's Comments** In general, most candidates achieved all of the available marks in these questions.

<table>
<tr><th colspan="3">Question</th><th>Answer/Indicative content</th><th>Marks</th><th>Guidance</th></tr>
<tr><td></td><td>b</td><td>i</td><td>
<table>
<tr><td>E</td><td>F</td><td>G</td><td>(E∧F)</td><td>(E∧G)</td><td>(E∧F)V (E∧G)</td></tr>
<tr><td>1</td><td>1</td><td>1</td><td>1</td><td>1</td><td>1</td></tr>
<tr><td>1</td><td>1</td><td>0</td><td>1</td><td>0</td><td>1</td></tr>
<tr><td>1</td><td>0</td><td>1</td><td>0</td><td>1</td><td>1</td></tr>
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1 mark for each of the pairs of rows.
</td><td>4

(AO1.2)</td><td></td></tr>
<tr><td></td><td></td><td>ii</td><td>(F∨G) ∧ E

One mark for the (F∨G)

One mark for the ∧ E</td><td>2

(AO2.2)</td><td>Accept:

(G∨F) ∧ E

E ∧ (F∨G)

E ∧ (G∨F)

Examiner's Comments
In general, most candidates achieved all of the available marks in these questions.</td></tr>
<tr><td></td><td></td><td></td><td>Total</td><td>9</td><td></td></tr>
</table>

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<tr><td>3</td><td></td><td>i</td><td>
<table>
<tr><th>A</th><th>B</th><th>C</th><th>D</th><th>Output</th></tr>
<tr><td>1</td><td>1</td><td>1</td><td>1</td><td>1</td></tr>
<tr><td>1</td><td>1</td><td>1</td><td>0</td><td>1</td></tr>
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<tr><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
</table>
1 Mark
1 Mark
1 Mark
1 Mark
</td><td>4

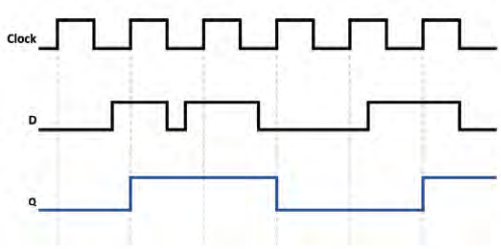
AO2.2</td><td>Examiner's Comment
This question was well received by candidates with most achieving full marks.</td></tr>
<tr><td></td><td></td><td>ii</td><td>(A ∨ B) ∨ (C ∨ D) ≡ Output

A ∨ B (1 Mark)

∨ (C ∨ D) (1 Mark)</td><td>2

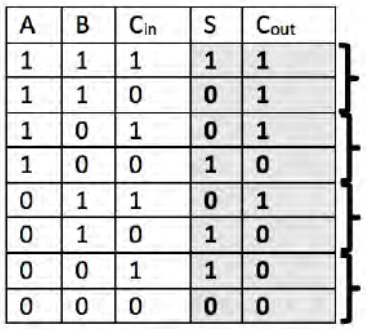
AO2.2</td><td>Accept answer without brackets.

Accept alternative notation i.e. OR, +

Examiner's Comment
Boolean expressions were in the main correct. All standard notations was credited provided it was used consistently.</td></tr>
<tr><td></td><td></td><td></td><td>Total</td><td>6</td><td></td></tr>
<tr><td>4</td><td>a</td><td></td><td>To store the state of a bit</td><td>1</td><td></td></tr>
<tr><td></td><td>b</td><td></td><td> 

One mark for each two correct clock cycles.</td><td>3</td><td></td></tr>
<tr><td></td><td></td><td></td><td>Total</td><td>4</td><td></td></tr>
</table>

Question			Answer/Indicative content	Marks	Guidance
5		i	A	1	
		ii	¬(A∨ B)	1	
		iii	A∨B	1	
			Total	3	

Question			Answer/Indicative content	Marks	Guidance
6	a	i	 1 Mark for rows 1 and 2 1 Mark for rows 3 and 4 1 Mark for rows 5 and 6 1 Mark for rows 7 and 8	4	
		ii	– Circuit adds two bits (and a carry bit) together / is an adder. – A B and C_{in} are added together – The result is given in S – And a carry bit in C_{out} (1 per –)	4	
	b	i	$S \equiv A \underline{\vee} B \underline{\vee} C_{in}$	1	Accept XOR instead of ∨ Accept $\oplus$ instead of ∨
		ii	$C_{out} \equiv ((A \underline{\vee} B) \wedge C_{in}) \vee (A \wedge B)$ One mark for $((A \vee B) \wedge C_{in})$ One mark for $\vee (A \wedge B)$	2	Accept XOR instead of ∨ Accept $\oplus$ instead of ∨ Accept AND instead of ∧ Accept OR instead of ∨ Accept + instead of ∨
			Total	11	