Answers

Answer 1

4(a)	X = ((P XOR Q) XOR R) Y = ((P XOR Q) AND R) OR (P AND Q) or $X = \overline{(\overline{P}.Q + P.\overline{Q})}.R + (\overline{P}.Q + P.\overline{Q}).\overline{R}$ $Y = (\overline{P}.Q + P.\overline{Q}).R + P.Q$ **One** mark for correct use of XOR **One** mark for correct use of AND **One** mark for correct use of OR **One** mark for X correct **One** mark for Y correct	**5**
4(b)(i)	X: Sum Y: Carry (out)	**2**
4(b)(ii)	Carry (in)	**1**

Answer 2

4(a)	For each expression, **2** marks all products correct no incorrect products seen, **1** mark 2 or 3 products correct, max 4 $X = \overline{A}.\overline{B}.C + \overline{A}.B.\overline{C} + A.\overline{B}.\overline{C} + A.B.C$ $Y = \overline{A}.B.C + A.\overline{B}.C + A.B.\overline{C} + A.B.C$	**4**
4(b)	**One** mark for each correct K-map max 2	**2**
4(c)(i)	**One** mark for OUTPUT X no loops OUTPUT Y **one** mark vertical loop correct **one** mark horizontal loops correct	**3**

OUTPUT X

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

OUTPUT Y

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

OUTPUT X

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

OUTPUT Y

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

4(c)(ii)	**One** mark for each correct product and no incorrect products max 3 A.B + B.C + A.C	**3**
4(d)	Logic circuit: Full Adder X: Sum Y: Carry	**3**

Answer 3

4(a)	For X **1** mark for all products correct For Y **2** marks for 3 products correct, no other products seen $X = \overline{A}.\overline{B}.\overline{C} + A.B.C$ $Y = \overline{A}.B.C + A.\overline{B}.C + A.B.C$	**3**
4(b)	**One** mark for each correct K-map max 2 **OUTPUT X** **AB** **C** \ **00** **01** **11** **10** **0** 1 0 0 0 **1** 0 0 1 0 **OUTPUT Y** **AB** **C** \ **00** **01** **11** **10** **0** 0 0 0 0 **1** 0 1 1 1	**2**
4(c)(i)	**One** mark for OUTPUT X no loops **One** mark for OUTPUT Y all loops correct and no others max 2 **OUTPUT X** **AB** **C** \ **00** **01** **11** **10** **0** 1 0 0 0 **1** 0 0 1 0 **OUTPUT Y** **AB** **C** \ **00** **01** **11** **10** **0** 0 0 0 0 **1** 0 1 1 1	**2**
4(c)(ii)	**One** mark for each correct product A.C + B.C	**2**

Answer 4

5	(logic) Circuit // bi-stable Two Memory // data storage // registers // storing one bit of data JK/SR/D/T SR/JK/T/D	**5**

Answer 5

<table>
<tr><td>3(a)</td><td>NOR</td><td>1</td></tr>
<tr><td>3(b)(i)</td><td>1 mark for X column, 1 mark for Y column
<table><tr><th>A</th><th>B</th><th>Working Space</th><th>X</th><th>Y</th></tr><tr><td>0</td><td>0</td><td></td><td>0</td><td>0</td></tr><tr><td>0</td><td>1</td><td></td><td>0</td><td>1</td></tr><tr><td>1</td><td>0</td><td></td><td>0</td><td>1</td></tr><tr><td>1</td><td>1</td><td></td><td>1</td><td>0</td></tr></table></td><td>2</td></tr>
<tr><td>3(b)(ii)</td><td>Half adder</td><td>1</td></tr>
<tr><td>3(b)(iii)</td><td>1 mark per bullet
∞ X is (used for) carry
∞ Y is (used for) sum</td><td>2</td></tr>
<tr><td>3(c)</td><td>1 mark per bullet for working (max 4)
$\bar{A}.\bar{B}.\bar{C}.\bar{D} + \overline{A.B}.\bar{C}.D + \overline{A.B}.C.D + \bar{A}.\overline{B.C}.D + \bar{A}.B.\bar{C}.\bar{D}$
$= \bar{A}.\bar{B}.\bar{C}.\bar{D} + \overline{A.B}.\bar{C}.D + \overline{A.B}.C.D + \bar{A}.\overline{B.C}.D + \bar{A}.B.\bar{C}.\bar{D} + \bar{A}.\bar{B}.\bar{C}.\bar{D}$
∞ Adding in a second copy of the first term (Use of Idempotent Law)
$= \bar{A}.\bar{B}.(\bar{C}.\bar{D} + \bar{C}.D + C.D + C.\bar{D}) + \bar{A}.\bar{C}.\bar{D}.(B + \bar{B})$
∞ Taking $\bar{A}.\bar{B}$ and $\bar{A}.\bar{C}.\bar{D}$ outside brackets (Associative Law)
$= \bar{A}.\bar{B}.(\bar{C}.(\bar{D} + D) + C.(D + \bar{D})) + \bar{A}.\bar{C}.\bar{D}.(B + \bar{B})$
∞ Grouping $\bar{C}.(\bar{D} + D) + C.(D + \bar{D})$ (Associative Law and Commutative Law)
$= \bar{A}.\bar{B}.(\bar{C}.(1) + C.(1)) + \bar{A}.\bar{C}.\bar{D}.(1)$
$= \bar{A}.\bar{B}.(\bar{C} + C) + \bar{A}.\bar{C}.\bar{D}.(1)$
$= \bar{A}.\bar{B}.(1) + \bar{A}.\bar{C}.\bar{D}.(1)$
∞ Replacing $(D + \bar{D})$ with 1 and replacing $(\bar{C} + C)$ with 1 (Use of Complement Law)
$= \bar{A}.\bar{B} + \bar{A}.\bar{C}.\bar{D}$
∞ Reducing first four terms to $\bar{A}.\bar{B}$ and reducing last two terms to $\bar{A}.\bar{C}.\bar{D}$ (Use of Identity Law)
1 mark for correct answer
$= \bar{A}.(\bar{B} + \bar{C}.\bar{D})$</td><td>5</td></tr>
</table>

Answer 6

3(a)(i) — **1**

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

3(a)(ii) — **2**

1 mark for each correct loop

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

3(a)(iii) — **2**

1 mark per bullet point

- $\overline{A}$
- $+\overline{B}$

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

3(b)(i) — **4**

1 mark correct values and order of row and column headings

3 marks fully correct table entries (based on headings) or
2 marks table entries contain one error (based on headings) or
1 mark table entries contain two errors (based on headings)

CD \ AB	00	01	11	10
00	0	0	1	1
01	0	0	1	1
11	1	1	0	0
10	1	1	0	0

3(b)(ii) — **2**

1 mark per loop

CD \ AB	00	01	11	10
00	0	0	1	1
01	0	0	1	1
11	1	1	0	0
10	1	1	0	0

3(b)(iii) — **2**

1 mark for each bullet point

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

$X = \overline{A}.C + A.\overline{C}$

Answer 7

4(a)	**1 mark** for 3 or 4 correct products **2 marks** for all 5 correct products $X = \overline{A}.\overline{B}.\overline{C} + \overline{A}.\overline{B}.C + \overline{A}.B.C + A.\overline{B}.C + A.B.C$	**2**
4(b)	**1 mark** for correct answer AB C 		00	01	11	10
---	---	---	---	---
0	1	0	0	0
1	1	1	1	1		**1**
4(c)	1 mark per correct loop AB C 		00	01	11	10
---	---	---	---	---
0	1	0	0	0
1	1	1	1	1		**2**
4(d)	**1 mark** per bullet point. • $\overline{A}.\overline{B}$ • $+C$ $X = \overline{A}.\overline{B} + C$ // $X = C + \overline{A}.\overline{B}$	**2**

Answer 8

2(a)(i)	1 mark for each 2 correct products, i.e. 3 marks for 6, 2 marks for 4 or 5, 1 mark for 2 or 3 $\mathbf{X = \overline{A}.\overline{B}.\overline{C} + \overline{A}.\overline{B}.C + \overline{A}.B.\overline{C} + \overline{A}.B.C + A.\overline{B}.\overline{C} + A.\overline{B}.C}$	**3**
2(a)(ii)	1 mark for the correct K-map AB C 		00	01	11	10
---	---	---	---	---
0	1	1	0	1
1	1	1	0	1		**1**
2(a)(iii)	1 mark for each correct loop AB C 		00	01	11	10
---	---	---	---	---
0	1	1	0	1
1	1	1	0	1		**2**

2(a)(iv)	1 mark per bullet point: • $\overline{A}$ • $+\overline{B}$ $X = \overline{A} + \overline{B}$ // $X = \overline{B} + \overline{A}$	2
2(b)	$X = \left(\overline{(\overline{W} + X).(Y + \overline{Z})}\right)$ One mark for correct use of De Morgan's law to + • $X = \overline{(\overline{W} + X)} + \overline{(Y + \overline{Z})}$ One mark for correct use of De Morgan's law + to • $X = \overline{\overline{W}}.\overline{X} + \overline{Y}.\overline{\overline{Z}}$ One mark for correct answer • $X = W.\overline{X} + \overline{Y}.Z$	3

Answer 9

4(a)(i)	**2** marks all products correct, **1** mark 2 or 3 products correct $X = \overline{A}.B.\overline{C} + \overline{A}.B.C + A.\overline{B}.\overline{C} + A.\overline{B}.C$	2
4(a)(ii)	**1** mark for all correct bits **AB** **C** / **00** **01** **11** **10** **0** 0 1 0 1 **1** 0 1 0 1	1
4(a)(iii)	**1** mark for each correct loop **AB** **C** / **00** **01** **11** **10** **0** 0 1 0 1 **1** 0 1 0 1	2
4(a)(iv)	**1** mark per bullet – allow follow through from **4(a)(iii)** ∝ $\overline{A}.B$ ∝ $+A.\overline{B}$ $X = \overline{A}.B + A.\overline{B}$	2

4(b)(i)	**1** mark per bullet max **2** ▫ Correct column headings and row headings – values only ▫ Correct column headings and row headings – order 1 mark for 2 correct rows/columns, 2 marks for 4 correct rows/columns (based on headings) max **2** **AB** **CD** **00** **01** **11** **10** **00** 0 1 1 0 **01** 0 1 1 0 **11** 0 1 0 0 **10** 0 1 0 0	**4**
4(b)(ii)	**1** mark for each correct loop **CD** **00** 0 1 1 0 **01** 0 1 1 0 **11** 0 1 0 0 **10** 0 1 0 0	**2**
4(b)(iii)	**1** mark per bullet $\bar{A}.B$ $+B.\bar{C}$ $X = \bar{A}.B + B.\bar{C}$	**2**

Answer 10

4(a)(i)	1 mark for 2 or 3 correct, 2 marks for 4 correct $X = \bar{A}.B.C + A.\bar{B}.C + A.B.\bar{C} + A.B.C$	**2**
4(a)(ii)	1 mark for the correct K-map **AB** **C** **00** **01** **11** **10** **0** 0 0 1 0 **1** 0 1 1 1	**1**
4(a)(iii)	1 mark for each loop max 3 **AB** **C** **00** **01** **11** **10** **0** 0 0 1 0 **1** 0 1 1 1	**3**

4(a)(iv)	1 mark for each pair. Allow follow through from **(iii)** - A.B - +B.C - +A.C $X = A.B + B.C + A.C$	**3**
4(b)(i)	1 mark per bullet point max 2: - Correct column headings and row headings – values only - Correct column headings and row headings – order 1 mark for 2 correct rows or columns, 2 marks for 4 correct rows or columns (based on headings) **AB** **CD** 	**00**	**01**	**11**	**10**
---	---	---	---	---
00	0	1	1	0
01	0	0	1	0
11	0	0	1	0
10	0	0	1	0		**4**
4(b)(ii)	1 mark per loop **AB** **CD** 	**00**	**01**	**11**	**10**
---	---	---	---	---
00	**0**	**1**	**1**	**0**
01	**0**	**0**	**1**	**0**
11	**0**	**0**	**1**	**0**
10	**0**	**0**	**1**	**0**		**2**
4(b)(iii)	1 mark per bullet point: - A.B - $+B.\overline{C}.\overline{D}$ $X = A.B + B.\overline{C}.\overline{D}$	**2**

Answer 11

3(a)

1 mark per bullet point to max 3:

- Correct use of Idempotent law $Y = Y.Y \quad Y = Y + Y$
- Correct use of Complement law $0 = Y.\overline{Y} \quad 1 = Y + \overline{Y}$
- Correct use of Distributive law $X(Y + Z) = X.Y + X.Z$
- Correct use of Redundancy law $X.\overline{Y} + Y = X + Y$
- Correct use of identity law $X.1 = X$

1 mark for the correct answer

For example:

$X = A.\overline{B}.\overline{C} + A.B.\overline{C} + A.B.C$	Idempotent law
$X = A.\overline{B}.\overline{C} + A.B.\overline{C} + A.B.\overline{C} + A.B.C$	Distributive law
$X = A.\overline{C}.(\overline{B} + B) + A.B.(\overline{C} + C)$	Complement/Inverse law
$X = A.\overline{C} + A.B$	
$X = A.(\overline{C} + B)$	Correct answer
$X = A.\overline{B}.\overline{C} + A.B.\overline{C} + A.B.C$	Distributive law
$X = A.\overline{C}.(\overline{B} + B) + A.B.C$	Complement/Inverse law
$X = A.\overline{C} + A.B.C$	
$X = A.(\overline{C} + B.C)$	Redundancy Law
$X = A.(\overline{C} + B)$	Correct answer

3(b)(i)

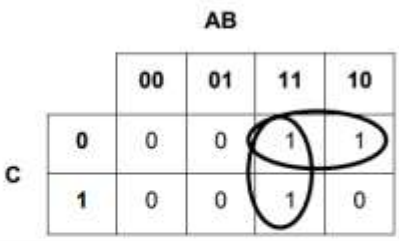
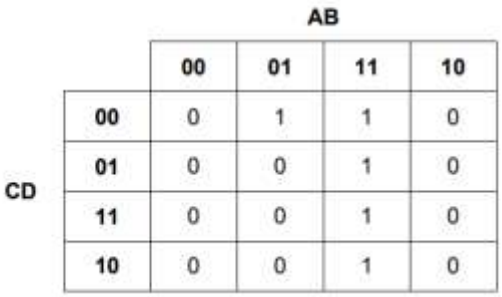
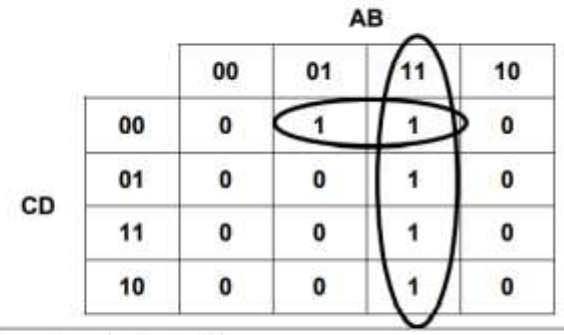
1 mark for first four as 0, 1 mark for 1011

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

3(b)(ii)

1 mark for correct K-map

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

3(b)(iii)	1 mark for each correct loop to max 2 
3(b)(iv)	1 mark per bullet point: • $A.\overline{C}$ • $+ A.B$ $X = A.\overline{C} + A.B$
3(c)(i)	1 mark per bullet point to max 2: • Correct column headings and row headings – values only • Correct column headings and row headings – order 1 mark for 2 correct rows or columns, 2 marks for 4 correct rows or columns (based on headings) 
3(c)(ii)	1 mark for each correct loop to max 2: 
3(c)(iii)	1 mark per bullet point: • A.B • $+ B.\overline{C}.\overline{D}$ $X = A.B + B.\overline{C}.\overline{D}$

Answer 12

3(a)	$X = A.(\overline{B} + (B \,.\, C))$ $\overline{B}.C$ 1 $\overline{B} + B.C$ 1 A. 1	3

3(b) — 2

A	B	C	Working Space	X
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

1 mark first four entries, 1 mark for the last four entries

3(c)(i) — 1

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

3(c)(ii) — 2

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

3(c)(iii) — 2

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

1 1

3(d) — 2

$X = A.(\overline{B} + (B \,.\, C))$

$X = A.(\overline{B} + C)$ 1

$X = A.\overline{B} + A.C$ 1 (dependent mark – must be correct outcome from previous line)

Answer 13

3(a) — 4

$S = (\overline{P} + (\overline{Q+R})) \,.\, R$

$\overline{P}$ 1

$(\overline{Q+R})$ 1

$(\overline{P} + (\overline{Q+R}))$ 1

. R (must be outside final brackets) 1

Or

$\overline{P}$ 1

$(\overline{Q+R})$ 1

$\overline{P} + (\overline{Q+R})$ 1

(.....). R 1

3(b) — 2

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

2 marks all correct, 1 mark seven correct, 0 marks six or fewer correct

3(c)(i) — 1

PQ

R	00	01	11	10
0	0	0	0	0
1	1	1	0	0

3(c)(ii) — 1

PQ

R	00	01	11	10
0	0	0	0	0
1	1	1	0	0

3(c)(iii) — 1

$S = \overline{P} \cdot R$

3(d) — 3

$S = (\overline{P} + (\overline{Q+R})) \cdot R$

$S = (\overline{P} + (\overline{Q} \cdot \overline{R})) \cdot R \;//\; \overline{P} \cdot R + (\overline{Q+R}) \cdot R$ 1

$S = (\overline{P} \cdot R) + (\overline{Q} \cdot \overline{R} \cdot R)$ 1

$S = \overline{P} \cdot R + \overline{Q} \cdot 0$)

$S = \overline{P} \cdot R + 0$) 1

$S = \overline{P} \cdot R$

Answer 14

5(a)(i) — 1

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

5(a)(ii) — **1**

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	1
1	1	1	0

5(b)(i) — **3**

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

5(b)(ii) — **2**

- Q and $\overline{Q}$ have same value
- Q and $\overline{Q}$ should be complements of each other
- Flip-flop becomes unstable

1 mark for each point, **max 2**

5(c)(i) — **4**

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

1 mark per shaded row

5(c)(ii) — **2**

- S-R flip-flop has an invalid combination of S and R // The S_R flip flop allows both Q and $\overline{Q}$ to have the same value // S-R flip-flop inputs may arrive at different times 1
- The J-K flip-flop does not allow for Q and $\overline{Q}$ to have the same value // All four combination of values for J and K are valid // J-K flip-flop incorporates a clock pulse for synchronisation 1

5(d) — **2**

- A flip-flop can store either a 0 or a 1
- Computers use bits to store data
- Flip-flops can therefore be used to store bits (of data)
- Memory can be created from flip-flops

1 mark for valid point, **max 2**

Answer 15

5(a) — **1**

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

5(b) — **4**

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

5(c)(i) — Clock (pulse) — **1**

5(c)(ii) — **4**

Max 2 marks per problem – **max 4 marks**

Problem 1

- One combination of S and R gives NOT valid / indeterminate output // Q and $\overline{Q}$ have the same value
- The JK flip-flop does not allow for Q and $\overline{Q}$ to have the same value for any combination of inputs // $\overline{Q}$ and Q have to be complementary

Problem 2

- Inputs may not arrive at the same time
- The JK flip-flop has a clock pulse to synchronise inputs

Answer 16

5 (a) — **1**

A	B	X
0	0	**1**
0	1	**1**
1	0	**1**
1	1	**0**

(b) (i) — **1 1 1 1**

S	R	Q	$\overline{Q}$
1	0	**0**	**1**
1	1	**0**	**1**
0	1	**1**	**0**
1	1	**1**	**0**
0	0	**1**	**1**

(ii)	S = 0 R = 0 Produces Q = 1 , $\overline{Q}$ =1 // Q and $\overline{Q}$ have same value But Q and $\overline{Q}$ should be complements of each other Becomes unstable	1 1 1 1 Max 3
(c) (i)	Clock (pulse)	1
(ii)	All four possibilities are valid The 1-1 combination changes output to logical complement Unstable state avoided Invalid state cannot occur // the flip-flop is stable	1 1 1 1 Max 1
(d)	Memory // data storage Stores a single bit	1 1

Answer 17

4 (a) (i)

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

1 mark for each correct column (A and B)

[2]

(ii) Half adder [1]

(iii) C // Carry [1]
S // Sum [1]

represents the carry part of the addition of two bits [1]
represents the sum part of the addition of two bits [1]

(b) (i) A. [1]
(A.B + C) [1]

(ii) Allow follow through from **(b)(i)**

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

1 mark for each correct simplification line – max 2 [2]
1 mark for A.(B+C) if correct answer to part **(b)(i)** [1]

Answer 18

5 (a) (i)

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

1 mark each column

If zero marks then
6 or 7 pairs correct – 1 mark

[2]

(ii) Full adder [1]

(iii) C / Carry [1]
S / Sum [1]
represents the carry part of the addition of three bits [1]
represents the sum part of the addition of three bits [1]

(b) (i) A. [1]
(A+B).C [1]

(ii) Allow follow through from **(b)(i)**

A. ((A+B).C)
= A.(A.C + B.C)
= A.A.C +A.B.C
= A.C + A.B.C
= A.C (1 + B)
=A.C.1
= A.C

1 mark for each correct simplification line – max 3 [3]
1 mark for A.C if correct answer to part **(b)(i)** [1]

[4]

Answer 19

4 (a) (i)

Circuit 1		
A	B	X
0	0	**1**
0	1	**1**
1	0	**1**
1	1	**0**

1

(ii)

Circuit 2		
A	B	X
0	0	**1**
0	1	**1**
1	0	**1**
1	1	**0**

1

(b) (i)

- circuit 1: $\overline{A.B}$ — 1
- circuit 2: $\overline{A} + \overline{B}$ — 1

(ii) $\overline{A.B} \equiv \overline{A} + \overline{B}$ — 1

(c) $\overline{\overline{(A+B).B}}$

Mark as follows:

$\overline{(A+B)}$ — 1

$.B$ — 1

bar over whole expression — 1

(d)

$\overline{\overline{(A+B).B}}$

$= \overline{\overline{(A+B)}} + \overline{B}$ — 1

$= (A+B) + \overline{B}$ — 1

$= A + (B + \overline{B})$ — 1

$= A + 1$ — 1

$= 1$ — 1

allow f.t. from **(c)** — [max 3]

Question 20

5 (a) (i) $\overline{A}.B.C +$ [1]

$A.B.\overline{C}$ [1]

$+$

$A.B.C$ [1]

(ii)

AB

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

[1]

(iii)

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

1 mark for each loop

Allow f.t. from **(ii)**

[2]

(iv) X =

A.B [1]

+ B.C [1]

Allow f.t. from **(iii)**

(b) (i)

CD \ AB	00	01	11	10
00	0	1	1	0
01	0	0	0	0
11	0	0	1	0
10	0	1	1	0

1 mark row headings

1 mark column headings

1 mark per 2 correct rows (based on headings)

[4]

(ii)

CD \ AB	00	01	11	10
00	0	1	1	0
01	0	0	0	0
11	0	0	1	0
10	0	1	1	0

1 mark for loop with two 1s

1 mark for looping the four 1s

[2]

(iii) X =

$B.\overline{D}$ [1]

+ A.B.C [1]

Answer 21

5 (a) (i)

$$Z = P.\overline{Q}.\overline{R} +$$ [1]

$$P.\overline{Q}.R +$$ [1]

$$P.Q.R$$ [1]

(ii)

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

[1]

(iii) 1 mark each loop

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

Allow f.t. from **(ii)** [2]

(iv)

$$Z =$$

$$P.\overline{Q}$$ [1]

$$+P.R$$ [1]

Allow f.t. from **(iii)**

(b) (i) 1 mark row headings. 1 mark column headings.
1 mark per 2 correct rows (based on headings)

RS \ PQ	00	01	11	10
00	0	0	0	0
01	0	1	1	1
11	0	1	1	0
10	0	0	0	0

[4]

(ii) 1 mark for loop with two 1s; 1 mark for loop with four 1s

RS \ PQ	00	01	11	10
00	0	0	0	0
01	0	1	1	1
11	0	1	1	0
10	0	0	0	0

Allow f.t. from **(i**
–1 for each incorrect grouping, max. 2 errors [2]

(iii)

$Z = Q.S$ [1]

$+P.R.\overline{S}$ [1]

Allow f.t. from **(ii).** –1 error if more than 2 terms

[Total: 16]