Question No. 1

a)	$X=A.(\overline{A}+\overline{B})$ A. [1] $\overline{A}$ $\overline{B}$ [1] + [1]	**3**
b)	$X = A \,.\, \overline{A\overline{B}}$ $X = A.\overline{A} + A.\overline{B}$ [1] $= 0 + A.\overline{B}$ [1] $= A.\overline{B}$ [1]	**3**
c)	logic circuit has: 1 AND gate and 1 NOT gate [1] inputs to one NOT gate is B [1] inputs to AND gate are A and output from NOT gate [1]	**3**
d)	A B X Y 0 0 0 0 [1] 0 1 0 1 [1] 1 0 0 1 [1] 1 1 1 0 [1]	**4**
e)	half adder [1]	**1**

Question No. 2

<table>
<tr><td>a) i)</td><td>
<table>
<tr><th colspan="2">Input</th><th colspan="2">Output</th></tr>
<tr><th>X</th><th>Y</th><th>A</th><th>B</th></tr>
<tr><td>0</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>0</td><td>1</td><td>0</td><td>1</td></tr>
<tr><td>1</td><td>0</td><td>0</td><td>1</td></tr>
<tr><td>1</td><td>1</td><td>1</td><td>0</td></tr>
</table>
1 mark for each correct column (A and B)
</td><td>2</td></tr>
<tr><td>a) ii)</td><td>Half adder</td><td>1</td></tr>
<tr><td>a) iii)</td><td>C // Carry
S // Sum

represents the carry part of the addition of two bits
represents the sum part of the addition of two bits</td><td>4</td></tr>
<tr><td>b) i)</td><td>A.
(A.B + C)</td><td>2</td></tr>
<tr><td>b) ii)</td><td>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
1 mark for A.(B+C) if correct answer to part (b)(i)</td><td>3</td></tr>
</table>

Question No. 3

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

a) ii) Full adder **1**

a) iii)
C / Carry
S / Sum
represents the carry part of the addition of three bits
represents the sum part of the addition of three bits
4

b) i)
A.
(A+B).C
2

b) 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

Question No. 4

<table>
<tr><td>a)</td><td>NOR</td><td>1</td></tr>
<tr><td>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>b) ii)</td><td>Half adder</td><td>1</td></tr>
<tr><td>b) iii)</td><td>1 mark per bullet
X is (used for) carry
Y is (used for) sum</td><td>2</td></tr>
</table>

c)	**1 mark** per bullet for working (**max 4**) $\bar{A}.\bar{B}.\bar{C}.\bar{D} + \overline{A.B}.\bar{C}.D + \overline{A.B}.C.D + \bar{A}.\overline{B.C}.\bar{D} + \bar{A}.B.\bar{C}.\bar{D}$ $= \bar{A}.\bar{B}.\bar{C}.\bar{D} + \overline{A.B}.\bar{C}.D + \overline{A.B}.C.D + \bar{A}.\overline{B.C}.\bar{D} + \bar{A}.B.\bar{C}.\bar{D} + \bar{A}.\bar{B}.\bar{C}.\bar{D}$ • 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 $= \bar{A}.(\bar{B} + \bar{C}.\bar{D})$	5

Question No. 5

a)	X = ((P XOR Q) XOR R) Y = ((P XOR Q) AND R) OR (P AND Q) or $X = \overline{(\bar{P}.Q + P.\bar{Q})}.R + (\bar{P}.Q + P.\bar{Q}).\bar{R}$ $Y = (\bar{P}.Q + P.\bar{Q}).R + P.Q$ **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**
b) i)	X: Sum Y: Carry (out)	**2**
b) ii)	Carry (in)	**1**

Question No. 6

a) — **3**

One mark for working, (all three columns P, Q and R)
One mark for each correct column Y, Z

A	B	C	P	Q	R	Y	Z
0	0	0	0	0	0	0	0
0	0	1	0	0	0	1	0
0	1	0	1	0	0	1	0
0	1	1	1	0	1	0	1
1	0	0	1	0	0	1	0
1	0	1	1	0	1	0	1
1	1	0	0	1	0	0	1
1	1	1	0	1	0	1	1

b) — **1**

Full adder

c) — **4**

One mark for each point

$Y = \overline{A}\,\overline{B}\,C + \overline{A}\,B\,\overline{C} + A\,\overline{B}\,\overline{C} + A\,B\,C$
Purpose: Sum bit

$Z = \overline{A}\,B\,C + A\,\overline{B}\,C + A\,B\,\overline{C} + A\,B\,C$
Purpose: Carry output

Question No. 7

a)	**One mark** per bullet point to **max 3** • Circuit / electronic components (construction) • With **two states** • Used for data storage elements // memory • …to store 1 bit of data	**3**
b)	**One mark** per bullet point to **max 2** • SR flip-flop has undefined / invalid / indeterminate state // JK flip-flop is stable • Description of undefined / invalid / indeterminate state for SR // Description of why JK flip flop is stable • JK flip flop has a clock pulse	**2**

Question No. 8

a) — **1**

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

b) i) — **4**

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**

b) ii) — **3**

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

c) i) — Clock (pulse) — **1**

c) ii) — **1**

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

d) — **2**

Memory // data storage
Stores a single bit

Question No. 9

a) **1**

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

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)

c) i) **1**

Clock (pulse)

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

Question No. 10

a) i) — 1

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

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

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	

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**

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

c) ii)	• 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	**2**
d)	• 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**	**2**

Question No. 11

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

Question No. 12

a) i) — 1

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

a) ii) — 1

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

b) i) — 2

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

b) ii) — 1

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

c) — 3

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

Mark as follows:

$\overline{(A+B)}$

$.B$

bar over whole expression

d) — 3

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

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

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

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

$= A + 1$

$= 1$

allow f.t. from **(c)**

Question No. 13

a) i) — 1

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

a) ii) — 1

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

b) i) — 2

circuit 1 $\overline{A+B}$
circuit 2 $\overline{A}\,.\,\overline{B}$

b) ii) — 1

$\overline{A+B} \equiv \overline{A}\,.\,\overline{B}$

c) — 3

$\overline{\overline{(A.B)}+B}$
mark as :
$\overline{(A.B)}$
$+B$
bar over whole expression

d) — 3

$\overline{\overline{(A.B)}+B}$
$= \overline{\overline{(A.B)}}\,.\,\overline{B}$
$= (A.B).\overline{B}$
$= A.(B.\overline{B})$
$= A.0$
$= 0$

allow f.t. from (c)

Question No. 14

a) i) — **3**

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

a) ii) — **1**

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

a) iii) — **2**

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)**

a) iv) — **2**

$X = A.B + B.C$

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

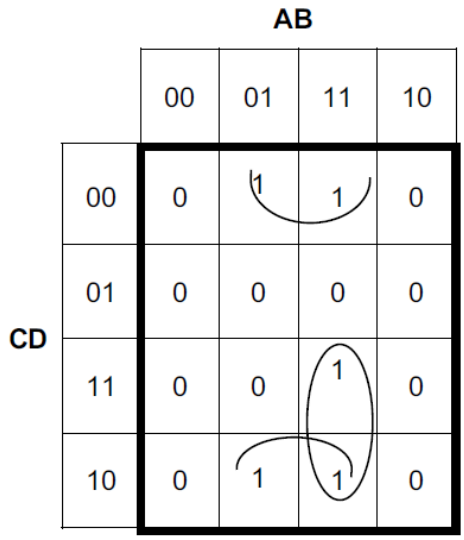
b) i) — **4**

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

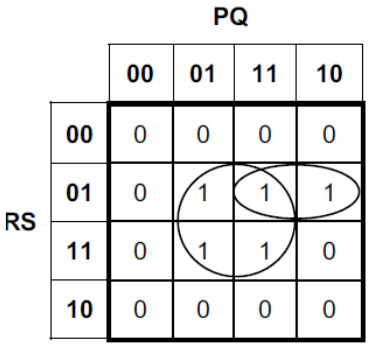
1 mark column headings

1 mark per 2 correct rows (based on headings)

b) ii)	 1 mark for loop with two 1s 1 mark for looping the four 1s	**2**
b) iii)	$X = B.\overline{D} + A.B.C$	**2**

Question No. 15

<table>
<tr><td>a) i)</td><td>$Z=P.\overline{Q}.\overline{R} + P.\overline{Q}.R + P.Q.R$</td><td>3</td></tr>
<tr><td>a) ii)</td><td>PQ
<table><tr><td></td><td>00</td><td>01</td><td>11</td><td>10</td></tr><tr><td>0</td><td>0</td><td>0</td><td>0</td><td>1</td></tr><tr><td>1</td><td>0</td><td>0</td><td>1</td><td>1</td></tr></table>R</td><td>1</td></tr>
<tr><td>a) iii)</td><td>1 mark each loop
PQ
<table><tr><td></td><td>00</td><td>01</td><td>11</td><td>10</td></tr><tr><td>0</td><td>0</td><td>0</td><td>0</td><td>1</td></tr><tr><td>1</td><td>0</td><td>0</td><td>1</td><td>1</td></tr></table>R
Allow f.t. from (ii)</td><td>2</td></tr>
<tr><td>a) iv)</td><td>$Z= P.\overline{Q} + P.R$
Allow f.t. from (iii)</td><td>1</td></tr>
<tr><td>b) i)</td><td>) 1 mark row headings. 1 mark column headings.
1 mark per 2 correct rows (based on headings)
PQ
<table><tr><td></td><td>00</td><td>01</td><td>11</td><td>10</td></tr><tr><td>00</td><td>0</td><td>0</td><td>0</td><td>0</td></tr><tr><td>01</td><td>0</td><td>1</td><td>1</td><td>1</td></tr><tr><td>11</td><td>0</td><td>1</td><td>1</td><td>0</td></tr><tr><td>10</td><td>0</td><td>0</td><td>0</td><td>0</td></tr></table>RS</td><td>4</td></tr>
</table>

b) ii)	1 mark for loop with two 1s; 1 mark for loop with four 1s  Allow f.t. from **(i** –1 for each incorrect grouping, max. 2 errors	**2**
b) iii)	$Z = Q.S + P.R.\overline{S}$ Allow f.t. from **(ii).** –1 error if more than 2 terms	**2**

Question No. 16

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

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

c) i) — **1**

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

c) ii) — **1**

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

c) iii)	$S = \overline{P} \cdot R$	**1**
d)	$S = (\overline{P} + (\overline{Q+R})) \cdot R$ $S = (\overline{P} + (\overline{Q} \cdot \overline{R})) \cdot R$ // $\overline{P} \cdot R + (\overline{Q+R}) \cdot R$ 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 $S = \overline{P} \cdot R$	**3**

Question No. 17

a) — **3**

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

$B.C$ 1

$\overline{B} + B.C$ 1

$A.$ 1

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

c) i) — **1**

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

c) ii) — **2**

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

c) iii) — **2**

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

1 1

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)

Question No. 18

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

<table>
<tr>
<td>b) ii)</td>
<td>1 mark for each correct loop
<table>
<tr><th>CD</th><th>00</th><th>01</th><th>11</th><th>10</th></tr>
<tr><td>00</td><td>0</td><td>1</td><td>1</td><td>0</td></tr>
<tr><td>01</td><td>0</td><td>1</td><td>1</td><td>0</td></tr>
<tr><td>11</td><td>0</td><td>1</td><td>0</td><td>0</td></tr>
<tr><td>10</td><td>0</td><td>1</td><td>0</td><td>0</td></tr>
</table>
</td>
<td>2</td>
</tr>
<tr>
<td>b) iii)</td>
<td>1 mark per bullet
$\bar{A}.B$
$+B.\bar{C}$
$X = \bar{A}.B + B.\bar{C}$</td>
<td>2</td>
</tr>
</table>

Question No. 19

<table>
<tr><td>a) i)</td><td>1 mark for 2 or 3 correct, 2 marks for 4 correct
$X = \bar{A}.B.C + A.\bar{B}.C + A.B.\bar{C} + A.B.C$</td><td>2</td></tr>
<tr><td>a) ii)</td><td>1 mark for the correct K-map
<table><tr><td></td><td></td><td colspan="4">AB</td></tr><tr><td></td><td></td><td>00</td><td>01</td><td>11</td><td>10</td></tr><tr><td>C</td><td>0</td><td>0</td><td>0</td><td>1</td><td>0</td></tr><tr><td></td><td>1</td><td>0</td><td>1</td><td>1</td><td>1</td></tr></table></td><td>1</td></tr>
<tr><td>a) iii)</td><td>1 mark for each loop max 3
<table><tr><td></td><td></td><td colspan="4">AB</td></tr><tr><td></td><td></td><td>00</td><td>01</td><td>11</td><td>10</td></tr><tr><td>C</td><td>0</td><td>0</td><td>0</td><td>1</td><td>0</td></tr><tr><td></td><td>1</td><td>0</td><td>1</td><td>1</td><td>1</td></tr></table></td><td>2</td></tr>
<tr><td>a) iv)</td><td>1 mark for each pair. Allow follow through from (iii)
• A.B
• +B.C
• +A.C
$X = A.B + B.C + A.C$</td><td>2</td></tr>
</table>

b) i) — 4

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)

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

b) ii) — 2

1 mark per loop

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

b) iii) — 2

1 mark per bullet point:

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

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

Question No. 20

a) — **4**

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

b) i) — **2**

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

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	1
1	1	1	1

1 mark

1 mark

b) ii) — **1**

1 mark for correct K-map

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

b) iii) — **2**

1 mark for each correct loop to max 2

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

b) iv) — **2**

1 mark per bullet point:

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

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

Question No. 21

a) i) — **1**

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

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

a) iii) — **2**

1 mark per bullet point

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

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

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

<table>
<tr>
<td>b) ii)</td>
<td>1 mark per loop

<table>
<tr><td></td><td colspan="4">AB</td></tr>
<tr><td>CD</td><td>00</td><td>01</td><td>11</td><td>10</td></tr>
<tr><td>00</td><td>0</td><td>0</td><td>1</td><td>1</td></tr>
<tr><td>01</td><td>0</td><td>0</td><td>1</td><td>1</td></tr>
<tr><td>11</td><td>1</td><td>1</td><td>0</td><td>0</td></tr>
<tr><td>10</td><td>1</td><td>1</td><td>0</td><td>0</td></tr>
</table>
</td>
<td>2</td>
</tr>
<tr>
<td>b) iii)</td>
<td>1 mark for each bullet point

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

$X = \overline{A}.C + A.\overline{C}$</td>
<td>2</td>
</tr>
</table>

Question No. 22

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**
b)	**1 mark** for correct answer AB C 00 01 11 10 0: 1 0 0 0 1: 1 1 1 1	**1**
c)	1 mark per correct loop AB C 00 01 11 10 0: 1 0 0 0 1: 1 1 1 1	**2**
d)	**1 mark** per bullet point. • $\overline{A}.\overline{B}$ • $+C$ $X = \overline{A}.\overline{B} + C$ // $X = C + \overline{A}.\overline{B}$	**2**

Question No. 23

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 $X = \overline{A}.\overline{B}.\overline{C} + \overline{A}.B.C + \overline{A}.B.\overline{C} + \overline{A}.B.C + A.\overline{B}.\overline{C} + A.\overline{B}.C$	**3**
a) ii)	1 mark for the correct K-map AB / C C=0: 1 1 0 1 C=1: 1 1 0 1	**1**
a) iii)	1 mark for each correct loop AB / C C=0: 1 1 0 1 C=1: 1 1 0 1	**2**
a) iv)	1 mark per bullet point: • $\overline{A}$ • $+\overline{B}$ $X = \overline{A} + \overline{B}$ // $X = \overline{B} + \overline{A}$	**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**

Question No. 24

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**
b)	**One** mark for each correct K-map max 2 OUTPUT X AB OUTPUT Y AB C 0 0 1 0 1 0 0 1 0 1 1 0 1 0 0 1 1 1	**2**
c) i)	**One** mark for OUTPUT X no loops OUTPUT Y **one** mark vertical loop correct **one** mark horizontal loops correct OUTPUT X AB OUTPUT Y AB C 0 0 1 0 1 0 0 1 0 1 1 0 1 0 0 1 1 1	**3**
c) ii)	**One** mark for each correct product and no incorrect products max 3 A.B + B.C + A.C	**3**
d)	Logic circuit: Full Adder X: Sum Y: Carry	**3**

Question No. 25

<table>
<tr><td>a)</td><td>For X 1 mark for all products correct
For Y 2 marks for 3 products correct, no other products seen
$X = \overline{A}.\overline{B}.\overline{C} + A.B.C$
$Y = \overline{A}.B.C + A.\overline{B}.C + A.B.C$</td><td>3</td></tr>
<tr><td>b)</td><td>One mark for each correct K-map max 2

<table>
<tr><th></th><th colspan="4">OUTPUT X
AB</th><th colspan="4">OUTPUT Y
AB</th></tr>
<tr><th></th><th>00</th><th>01</th><th>11</th><th>10</th><th>00</th><th>01</th><th>11</th><th>10</th></tr>
<tr><th>0</th><td>1</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
<tr><th>C
1</th><td>0</td><td>0</td><td>1</td><td>0</td><td>0</td><td>1</td><td>1</td><td>1</td></tr>
</table></td><td>2</td></tr>
<tr><td>c) i)</td><td>One mark for OUTPUT X no loops
One mark for OUTPUT Y all loops correct and no others max 2

<table>
<tr><th></th><th colspan="4">OUTPUT X
AB</th><th colspan="4">OUTPUT Y
AB</th></tr>
<tr><th></th><th>00</th><th>01</th><th>11</th><th>10</th><th>00</th><th>01</th><th>11</th><th>10</th></tr>
<tr><th>0</th><td>1</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
<tr><th>C
1</th><td>0</td><td>0</td><td>1</td><td>0</td><td>0</td><td>1</td><td>1</td><td>1</td></tr>
</table></td><td>2</td></tr>
<tr><td>c) ii)</td><td>One mark for each correct product
A.C + B.C</td><td>2</td></tr>
</table>

Question No. 26

<table>
<tr><td>a) i)</td><td>One mark for 2 correct, two marks for 4 correct and no other terms
$X = \overline{P}.\overline{Q}.\overline{R}.\overline{S} + \overline{P}.\overline{Q}.R.\overline{S} + P.Q.\overline{R}.S + P.Q.R.S$</td><td>2</td></tr>
<tr><td>a) ii)</td><td>Two marks for fully correct K-map
One mark for a K-map with one error
Zero marks for a K-map with two or more errors

<table>
<tr><td></td><td></td><td colspan="4">PQ</td></tr>
<tr><td></td><td></td><td>00</td><td>01</td><td>11</td><td>10</td></tr>
<tr><td rowspan="4">RS</td><td>00</td><td>1</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>01</td><td>0</td><td>0</td><td>1</td><td>0</td></tr>
<tr><td>11</td><td>0</td><td>0</td><td>1</td><td>0</td></tr>
<tr><td>10</td><td>1</td><td>0</td><td>0</td><td>0</td></tr>
</table></td><td>2</td></tr>
<tr><td>a) iii)</td><td>One mark for each correct loop max two

<table>
<tr><td></td><td></td><td colspan="4">PQ</td></tr>
<tr><td></td><td></td><td>00</td><td>01</td><td>11</td><td>10</td></tr>
<tr><td rowspan="4">RS</td><td>00</td><td>1</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>01</td><td>0</td><td>0</td><td>1</td><td>0</td></tr>
<tr><td>11</td><td>0</td><td>0</td><td>1</td><td>0</td></tr>
<tr><td>10</td><td>1</td><td>0</td><td>0</td><td>0</td></tr>
</table></td><td>2</td></tr>
<tr><td>a) iv)</td><td>One mark per point
• $\overline{P}.\overline{Q}.\overline{S}$
• $+P.Q.S$
$X = \overline{P}.\overline{Q}.\overline{S} + P.Q.S$</td><td>2</td></tr>
<tr><td>b)</td><td>One mark for correct use of distributive law
One mark for correct use of complementary law
One mark for correct use of redundancy law
One mark for correct use of idempotent law
Max two

$X = \overline{P}.\overline{Q}.\overline{R}.\overline{S} + \overline{P}.\overline{Q}.R.\overline{S} + P.Q.\overline{R}.S + P.Q.R.S$
$X = \overline{P}.\overline{Q}.\overline{S}(\overline{R} + R) + P.Q.S(\overline{R} + R)$
$X = \overline{P}.\overline{Q}.\overline{S} + P.Q.S \;//\; \overline{P}.\overline{Q}.\overline{S}(1) + P.Q.S(1)$</td><td>2</td></tr>
</table>

Question No. 27

<table>
<tr><td>a) i)</td><td>One mark for 2 correct terms or two marks for 4 correct terms and no other terms
$X = \overline{P}.Q.\overline{R}.\overline{S} + \overline{P}.Q.\overline{R}.\overline{S} + P.\overline{Q}.R.S + P.Q.R.S$</td><td>2</td></tr>
<tr><td>a) ii)</td><td>Two marks for fully correct K-map
One mark for a K-map with one error
Zero marks for a K-map with two or more errors

<table>
<tr><td></td><td></td><td colspan="4">PQ</td></tr>
<tr><td></td><td></td><td>00</td><td>01</td><td>11</td><td>10</td></tr>
<tr><td rowspan="4">RS</td><td>00</td><td>1</td><td>1</td><td>0</td><td>0</td></tr>
<tr><td>01</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>11</td><td>0</td><td>0</td><td>1</td><td>1</td></tr>
<tr><td>10</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
</table></td><td>2</td></tr>
<tr><td>a) iii)</td><td>One mark for each correct loop max 2

<table>
<tr><td></td><td></td><td colspan="4">PQ</td></tr>
<tr><td></td><td></td><td>00</td><td>01</td><td>11</td><td>10</td></tr>
<tr><td rowspan="4">RS</td><td>00</td><td>1</td><td>1</td><td>0</td><td>0</td></tr>
<tr><td>01</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>11</td><td>0</td><td>0</td><td>1</td><td>1</td></tr>
<tr><td>10</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
</table></td><td>2</td></tr>
<tr><td>a) iv)</td><td>One mark per point
• $\overline{P}\overline{R}.\overline{S}$
• $+P.R.S$
$X = \overline{P}\overline{R}.\overline{S} + P.R.S$</td><td>2</td></tr>
<tr><td>b)</td><td>One mark for correct use of distributive law
One mark for correct use of complementary law
One mark for correct use of redundancy law
Max two

e.g.
$X = \overline{P}.\overline{Q}.\overline{R}.\overline{S} + \overline{P}.Q.\overline{R}.\overline{S} + P.\overline{Q}.R.S + P.Q.R.S$
$X = \overline{P}.\overline{R}.\overline{S}(\overline{Q} + Q) + P.R.S(\overline{Q} + Q)$
$X = \overline{P}\overline{R}.\overline{S} + P.R.S \;//\; \overline{P}.\overline{R}.\overline{S}(1) + P.R.S(1)$</td><td>2</td></tr>
</table>

Question No. 28

<table>
<tr><td>a) i)</td><td>One mark for 2 or 3 correct, two marks for 4 correct
$X = \bar{P}.\bar{Q}.\bar{R}.\bar{S} + \bar{P}.\bar{Q}.\bar{R}.S + P.Q.R.\bar{S} + P.Q.R.S$</td><td>2</td></tr>
<tr><td>a) ii)</td><td>One mark for each correct pair of rows/columns to max 2
<table><tr><td></td><td></td><td colspan="4">PQ</td></tr><tr><td></td><td></td><td>00</td><td>01</td><td>11</td><td>10</td></tr><tr><td rowspan="4">RS</td><td>00</td><td>1</td><td>0</td><td>0</td><td>0</td></tr><tr><td>01</td><td>1</td><td>0</td><td>0</td><td>0</td></tr><tr><td>11</td><td>0</td><td>0</td><td>1</td><td>0</td></tr><tr><td>10</td><td>0</td><td>0</td><td>1</td><td>0</td></tr></table></td><td>2</td></tr>
<tr><td>a) iii)</td><td>One mark for each correct loop max 2
<table><tr><td></td><td></td><td colspan="4">PQ</td></tr><tr><td></td><td></td><td>00</td><td>01</td><td>11</td><td>10</td></tr><tr><td rowspan="4">RS</td><td>00</td><td>1</td><td>0</td><td>0</td><td>0</td></tr><tr><td>01</td><td>1</td><td>0</td><td>0</td><td>0</td></tr><tr><td>11</td><td>0</td><td>0</td><td>1</td><td>0</td></tr><tr><td>10</td><td>0</td><td>0</td><td>1</td><td>0</td></tr></table></td><td>2</td></tr>
<tr><td>a) iv)</td><td>One mark per bullet point
• $\overline{P}.\bar{Q}.\bar{R}$
• $+P.Q.R$
$X = \overline{P}.\bar{Q}.\bar{R} + P.Q.R$ // $X = P.Q.R + \overline{P}.\bar{Q}.\bar{R}$</td><td>2</td></tr>
<tr><td>b)</td><td>One mark for correct use of distributive law
One mark for correct use of complement law
$X = \bar{P}.\bar{Q}.\bar{R}(\bar{S} + S) + P.Q.R(\bar{S} + S)$
$X = \bar{P}.\bar{Q}.\bar{R}(1) + P.Q.R(1)$

or

Two marks for correct use of redundancy law

$X = (\bar{P}.\bar{Q}.\bar{R}).\bar{S} + (\bar{P}.\bar{Q}.\bar{R}).S + (P.Q.R).\bar{S} + (P.Q.R).S$
$X = \bar{P}.\bar{Q}.\bar{R} + P.Q.R$</td><td>2</td></tr>
</table>

Question No. 29

<table>
<tr><td>a) i)</td><td>One mark for 2 or 3 correct, 2 marks for 4 correct
$X = \bar{P}.\bar{Q}.\bar{R}.\bar{S} + \bar{P}.Q.R.S + P.\bar{Q}.\bar{R}.\bar{S} + P.Q.R.S$</td><td>2</td></tr>
<tr><td>a) ii)</td><td>One mark two correct rows/columns or
Two marks for four correct rows/columns
<table><tr><td></td><td></td><td colspan="4">PQ</td></tr><tr><td></td><td></td><td>00</td><td>01</td><td>11</td><td>10</td></tr><tr><td rowspan="4">RS</td><td>00</td><td>1</td><td>0</td><td>0</td><td>1</td></tr><tr><td>01</td><td>0</td><td>0</td><td>0</td><td>0</td></tr><tr><td>11</td><td>0</td><td>1</td><td>1</td><td>0</td></tr><tr><td>10</td><td>0</td><td>0</td><td>0</td><td>0</td></tr></table></td><td>2</td></tr>
<tr><td>a) iii)</td><td>One mark for each correct loop max 2
<table><tr><td></td><td></td><td colspan="4">PQ</td></tr><tr><td></td><td></td><td>00</td><td>01</td><td>11</td><td>10</td></tr><tr><td rowspan="4">RS</td><td>00</td><td>1</td><td>0</td><td>0</td><td>1</td></tr><tr><td>01</td><td>0</td><td>0</td><td>0</td><td>0</td></tr><tr><td>11</td><td>0</td><td>1</td><td>1</td><td>0</td></tr><tr><td>10</td><td>0</td><td>0</td><td>0</td><td>0</td></tr></table></td><td>2</td></tr>
<tr><td>a) iv)</td><td>One mark per bullet point
• $\bar{Q}\bar{R}.\bar{S}$
• $+Q.R.S$
$X = \bar{Q}\bar{R}.\bar{S} + Q.R.S$ or $X = Q.R.S + \bar{Q}\bar{R}.\bar{S}$</td><td>2</td></tr>
<tr><td>b)</td><td>One mark for correct use of distributive law
One mark for correct use of complement law
$X = \bar{Q}.\bar{R}.\bar{S}\left(\bar{P} + P\right) + Q.R.S(\bar{P} + P)$
$X = \bar{Q}.\bar{R}.\bar{S}(1) + Q.R.S(1)$
Or
Two marks for correct use of redundancy law
$X = \left(\bar{Q}.\bar{R}.\bar{S}\right)\bar{P} + \left(\bar{Q}.\bar{R}.\bar{S}\right)P + (Q.R.S)\bar{P} + (Q.R.S)P)$
$X = \bar{Q}.\bar{R}.\bar{S} + Q.R.S$</td><td>2</td></tr>
</table>

Question No. 30

A

One mark per two correct products **(Max 3)** — **3**

$(Z =) A \bar{B} \bar{C} D + A \bar{B} C D + A B \bar{C} \bar{D} + A B \bar{C} D + A B C \bar{D} + A B C D$

b) i)

One mark for every two correct rows or columns **(Max 2)** — **2**

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

b) ii)

One mark for correct loop **(Max 2)** — **2**

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

b) iii)

One mark per correct marking point **(Max 2)** — **2**

- **A B // A D**
- **+ A D // + A B**

$(Z =) A B + A D // A D + A B$

b) iv)

$(Z =) A (B + D) // A (D + B)$ — **1**