1	1	**Marks are for AO2 (apply)** **Marking guidance for examiners** • Award marks for working out until an incorrect step has been made. • If, in any one step, a candidate is simplifying different parts of an expression simultaneously award all relevant marks for this multiple stage but don't award any further marks for working in any parts simplified incorrectly. Example, if the expression P.P.(P+Q) + P.P.1 was changed to P.(P+Q)+P.0, the candidate would get one mark for simplifying the first part to P.(P+Q) and could get further marks for correctly simplifying this part of the expression further but should not be awarded marks for simplifying the incorrectly changed part P.0 (ie to 0) **Mark as follows** **MAX 3 marks for working** Award one mark each for applying the techniques below: • a successful application of De Morgan's Law (and any associated cancellation of NOTs) that produces a simpler expression. • successfully expanding brackets. Award one mark for each application of a Boolean identity **MAX 2**. **Note:** A simpler expression is one that is logically equivalent to the original expression but uses fewer logical operators. **Example working (1)** $\overline{\overline{A \cdot \overline{B}} \cdot \overline{\overline{A} \cdot (B + B)}}$ [use of $\overline{B} + 0 = \overline{B}$] $\overline{\overline{A \cdot \overline{B}} \cdot \overline{\overline{A} \cdot B}}$ [use of B + B = B] $A \cdot \overline{B} + \overline{A} \cdot B$ [application of De Morgan's Law] **Example working (2)** $A \cdot (\overline{B} + 0) + \overline{A} \cdot (B + B)$ [use of De Morgan's Law] $A \cdot \overline{B} + \overline{A} \cdot 0 + \overline{A} \cdot B + \overline{A} \cdot B$ [expansion of brackets]	4

		$A \cdot \overline{B} + \overline{A} \cdot B + \overline{A} \cdot B$ $A \cdot \overline{B} + \overline{A} \cdot B$ **Example working (3)** $A \cdot (\overline{B} + 0) + \overline{A} \cdot (B + B)$ $A \cdot \overline{B} + \overline{A} \cdot B$ **1 mark** for final answer A XOR B // A Exclusive OR B // A EOR B // A EXOR B // A $\oplus$ B	[use of $\overline{A} \cdot 0 = 0$ and removal] [application of $\overline{A} \cdot B + \overline{A} \cdot B = \overline{A} \cdot B$] [use of De Morgan's Law] [$\overline{B} + 0 = \overline{B}$ and $B+B=B$ means two marks for identities within brackets]	

2	1	**Mark is for AO1 (understanding)** OR; **A**. A+B // +	1

2	2	**Marks are for AO2 (apply)** **Marking guidance for examiners** • Award marks for working out until an incorrect step has been made. • If, in any one step, a candidate is simplifying different parts of an expression simultaneously award all relevant marks for this multiple stage but don't award any further marks for working in any parts simplified incorrectly. Example, if the expression P.P.(P+Q) + P.P.1 was changed to P.(P+Q)+P.0, the candidate would get one mark for simplifying the first part to P.(P+Q) and could get further marks for correctly simplifying this part of the expression further but should not be awarded marks for simplifying the incorrectly changed part P.0 (ie to 0) **Mark as follows** **1 mark** for final answer A **3 marks for working** **Max 3** for working. Award up to two marks for applying each one of the three techniques (one mark per application): • a successful application of De Morgan's Law (and any associated cancellation of NOTs) that produces a simpler expression • applying an identity other than cancelling NOTs that produces a simpler expression • successfully expanding brackets **Note:** A simpler expression is one that is logically equivalent to the original expression but uses fewer logical operators. **Note:** Any application of De Morgan's Law or expanding brackets which result in an expression which should be bracketed must be shown with brackets to be awarded a mark. **Example working (1)** $A \cdot (A + C) \cdot \overline{A} \rightarrow A \cdot \overline{A}$ [Absorption] $A \cdot \overline{A} \rightarrow 0$ [Complement] $\overline{(\overline{A} \cdot \overline{A \cdot B})} \rightarrow A + A \cdot B$ [De Morgan's Law] $A + A \cdot B \rightarrow A$ [Absorption] $0 + A \rightarrow A$ [Identity] **Example working (2)** $A \cdot (A + C) \cdot \overline{A} \rightarrow A \cdot \overline{A}$ [Absorption] $A \cdot \overline{A} \rightarrow 0$ [Complement] $\overline{(\overline{A} \cdot \overline{A \cdot B})} \rightarrow (\overline{\overline{A} \cdot (\overline{A} + \overline{B})})$ [De Morgan's Law] $(\overline{\overline{A} \cdot (\overline{A} + \overline{B})}) \rightarrow \overline{\overline{A} + \overline{A} \cdot \overline{B}}$ [Associative] $\overline{\overline{A} + \overline{A} \cdot \overline{B}} \rightarrow \overline{\overline{A}}$ [Absorption] $\overline{\overline{A}} \rightarrow A$ [Double Not] $0 + A \rightarrow A$ [Identity]	4

3	1	**4 marks are for AO2 (apply)** **Marking guidance for examiners** • Award marks for working out until an incorrect step has been made. If a student misses out some steps but does not make an error then continue marking. • If, in any one step, a candidate is simplifying different parts of an expression simultaneously award all relevant marks for this multiple stage but don't award any further marks for working in any parts simplified incorrectly. Example, if the expression P.P.(P+Q) + P.P.1 was changed to P.(P+Q)+P.0, the candidate would get one mark for simplifying the first part to P.(P+Q) and could get further marks for correctly simplifying this part of the expression further but should not be awarded marks for simplifying the incorrectly changed part P.0 (ie to 0) **Mark as follows** **1 mark** for final answer $\mathrm{A} \cdot \overline{\mathrm{C}}$ **Max 3 marks for working:** • **1 mark** for <u>each</u> application of an identity or theorem other than cancelling NOTs that produces a simpler expression. • **1 mark** for a <u>single</u> successful application of the distributive law that produces a simpler expression. **Note:** a simpler expression is one that is logically equivalent to the original expression but uses fewer logical operators. **Max 3** if answer is correct but any incorrect working or significant steps of working is missing. **Example working (1)** $\overline{\overline{\mathrm{A}+\mathrm{0}}+\mathrm{C}\cdot\mathrm{A}}$ [B. NOT B = 0] $(\mathrm{A}+\mathrm{0})\cdot\overline{\mathrm{C}\cdot\mathrm{A}}$ [Application of De Morgan's Law] $(\mathrm{A}+\mathrm{0})\cdot(\overline{\mathrm{C}}+\overline{\mathrm{A}})$ [Application of De Morgan's Law] $\mathrm{A}\cdot(\overline{\mathrm{C}}+\overline{\mathrm{A}})$ [A + 0 = A] $\mathrm{A}\cdot\overline{\mathrm{C}}+\mathrm{A}\cdot\overline{\mathrm{A}}$ [Expand brackets] $\mathrm{A}\cdot\overline{\mathrm{C}}+\mathrm{0}$ $[\mathrm{A}\cdot\overline{\mathrm{A}}=\mathrm{0}]$ $\mathrm{A}\cdot\overline{\mathrm{C}}$ $[\mathrm{A}+\mathrm{0}=\mathrm{A}]$ **Example working (2)** $(\mathrm{A}+\mathrm{B}\cdot\overline{\mathrm{B}})\cdot\overline{\mathrm{C}\cdot\mathrm{A}}$ [Application of De Morgan's Law] $(\mathrm{A}+\mathrm{0})\cdot\overline{\mathrm{C}\cdot\mathrm{A}}$ [B. NOT B = 0] $\mathrm{A}\cdot\overline{\mathrm{C}\cdot\mathrm{A}}$ [A + 0 = A] $\mathrm{A}\cdot(\overline{\mathrm{C}}+\overline{\mathrm{A}})$ [Application of De Morgan's Law] $\mathrm{A}\cdot\overline{\mathrm{C}}+\mathrm{A}\cdot\overline{\mathrm{A}}$ [Expand brackets] $\mathrm{A}\cdot\overline{\mathrm{C}}+\mathrm{0}$ $[\mathrm{A}\cdot\overline{\mathrm{A}}=\mathrm{0}]$ $\mathrm{A}\cdot\overline{\mathrm{C}}$ $[\mathrm{A}+\mathrm{0}=\mathrm{A}]$	4

<table>
<tr><th>Qu</th><th>Pt</th><th>Marking Guidance</th><th>Marks</th></tr>
<tr><td>4</td><td>1</td><td>
Marks are for AO2 (analyse)

1 mark for showing the correct truth table column for $\left(\mathrm{A}+\overline{\mathrm{B}}\right)\cdot\mathrm{B}$;

1 mark for showing the correct truth table column for $\left(\mathrm{A}+\overline{\mathrm{B}}\right)$;

<table>
<tr><th>$\mathbf{A}$</th><th>$\mathbf{B}$</th><th>$\overline{\mathbf{B}}$</th><th>$\left(\mathbf{A}+\overline{\mathbf{B}}\right)$</th><th>$\left(\mathbf{A}+\overline{\mathbf{B}}\right)\cdot\mathbf{B}$</th></tr>
<tr><td>0</td><td>0</td><td>1</td><td>1</td><td>0</td></tr>
<tr><td>0</td><td>1</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>1</td><td>0</td><td>1</td><td>1</td><td>0</td></tr>
<tr><td>1</td><td>1</td><td>0</td><td>1</td><td>1</td></tr>
</table>
1 mark for showing the correct answer as $\mathrm{A}\cdot\mathrm{B}$;
</td><td>3</td></tr>
</table>

<table>
<tr><th>Qu</th><th>Pt</th><th>Marking Guidance</th><th>Marks</th></tr>
<tr><td>4</td><td>2</td><td>

Marks are for AO2 (application)

Marking guidance for examiners

- Award marks for working out until an incorrect step has been made.
- If, in any one step, a candidate is simplifying different parts of an expression simultaneously award all relevant marks for this multiple stage but don't award any further marks for working in any parts simplified incorrectly. For example, if the expression P.P.(P+Q) + P.P.1 was changed to P.(P+Q)+P.0, the candidate would get one mark for simplifying the first part to P.(P+Q) and could get further marks for correctly simplifying this part of the expression further but should not be awarded marks for simplifying the incorrectly changed part P.0 (ie to 0).

1 mark for final answer of $A \cdot \overline{B}$;

3 marks for working

MAX 3 for working. Award up to two marks for applying each of the three techniques (one mark per application) to produce a simpler expression.

- Applying De Morgan's Theorem.
- Multiply and/or factorise brackets.
- Using a law or identity.

Note: A simpler expression is one that is logically equivalent to the original expression but uses fewer logical operators.

Example 1:

$\left(A+\overline{B}\right)\cdot\left(\overline{\overline{A}+B}\right)$	DMT
$\left(A+\overline{B}\right)\cdot\left(A\cdot\overline{B}\right)$	Multiply brackets
$A\cdot A\cdot\overline{B} + \overline{B}\cdot A\cdot\overline{B}$	X.X = X
$A\cdot\overline{B}+\overline{B}\cdot A$	X + X = X
$A\cdot\overline{B}$	

Example 2:

$\left(A+\overline{B}\right)\cdot\left(\overline{\overline{A}+B}\right)$	DMT
$\overline{\overline{\left(A+\overline{B}\right)}+\left(\overline{A}+B\right)}$	DMT
$\overline{\overline{A}\cdot B+\left(\overline{A}+B\right)}$	A + (A.X) = A
$\overline{\overline{A}+B}$	DMT
$A\cdot\overline{B}$	

</td><td>4</td></tr>
</table>

Qu	Pt	Marking Guidance	Marks
5	1	**Marks are for AO2 (application)** **1 mark** for each highlighted column L, N and Y completed correctly. **A**. Follow through for Y if column N is completed incorrectly.	3

A	B	C	L	M	N	X	Y
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	1	0	0	1
1	0	0	1	0	0	1	0
1	0	1	1	1	0	0	1
1	1	0	0	0	1	0	1
1	1	1	0	0	1	1	1

Qu	Pt	Marking Guidance	Marks
5	2	**Marks are for AO2 (application)** **2 marks:** $(A \oplus B) \cdot C + A \cdot B$ // $((A \cdot \bar{B}) + (\bar{A} \cdot B)) \cdot C + A \cdot B$ // $(\bar{A} \cdot B \cdot C) + (A \cdot (B + C))$ // **1 mark** for one of the following somewhere in the expression: • $(A \oplus B) \cdot C$ **I.** presence / absence of brackets around $A \oplus B$ • $((A \cdot \bar{B}) + (\bar{A} \cdot B)) \cdot C$ • $A \cdot B$ **Note:** If using a different algebraic notation refer to team leader.	2

Qu	Pt	Marking Guidance	Marks
5	3	**Marks are for AO2 (application)** **Marking guidance for examiners** • Award marks for working out until an incorrect step has been made. • If, in any one step, a candidate is simplifying different parts of an expression simultaneously award all relevant marks for this multiple stage but don't award any further marks for working in any parts simplified incorrectly. Example, if the expression P.P.(P+Q) + P.P.1 was changed to P.(P+Q)+P.0, the candidate would get one mark for simplifying the first part to P.(P+Q) and could get further marks	4

for correctly simplifying this part of the expression further but should not be awarded marks for simplifying the incorrectly changed part P.0 (ie to 0).

Mark as follows:

MAX 3 marks for working

Award one mark each for applying the techniques below:

- A successful application of De Morgan's Law (and any associated cancellation of NOTs) that produces a simpler expression.
- Successfully expanding brackets.
- Extracting common factors from terms.

Award one mark for each application of a Boolean identity **MAX 2**.

Note: A simpler expression is one that is logically equivalent to the original expression but uses fewer logical operators.

1 mark for final answer: B

$\overline{\overline{\overline{A} + \overline{B}}} + B \cdot \overline{A} \cdot 1$	[use of $\overline{C} + C = 1$]
$\overline{\overline{\overline{A} + \overline{B}}} + B \cdot \overline{A}$	[use of $\overline{A} \cdot 1 = \overline{A}$]
$A \cdot B + B \cdot \overline{A}$	[use of de Morgan's Law]
$B \cdot (A + \overline{A})$	[factoring B]
$B \cdot 1$	[use of common factor - $B \cdot (A + \overline{A}) = B \cdot 1$]
B	[use of $B \cdot 1 = B$]

Alternative answer 1

$\overline{\overline{\overline{A} + \overline{B}}} + B \cdot \overline{A} \cdot 1$	[use of $\overline{C} + C = 1$]
$\overline{\overline{\overline{A} + \overline{B}}} + B \cdot \overline{A}$	[use of $\overline{A} \cdot 1 = \overline{A}$]
$\overline{(\overline{A} + \overline{B}) \cdot \overline{B \cdot \overline{A}}}$	[use of de Morgan's Law]
$\overline{(\overline{A} + \overline{B}) \cdot (\overline{B} + A)}$	[use of de Morgan's Law]
$\overline{\overline{A} \cdot \overline{B} + \overline{A} \cdot A + \overline{B} \cdot \overline{B} + \overline{B} \cdot A}$	[expansion of brackets]
$\overline{\overline{A} \cdot \overline{B} + \overline{B} \cdot \overline{B} + \overline{B} \cdot A}$	[use of $\overline{A} \cdot A = 0$, $A + 0 = A$]
$\overline{\overline{A} \cdot \overline{B} + \overline{B} + \overline{B} \cdot A}$	[use of $\overline{B} \cdot \overline{B} = \overline{B}$]
$\overline{\overline{B} + \overline{B} \cdot A}$	[use of $\overline{A} \cdot \overline{B} + \overline{B} = \overline{B}$]
$\overline{\overline{B}}$	[use of $\overline{B} + \overline{B} \cdot A = \overline{B}$]
B	[Negation of double NOTs]

Qu	Pt	Marking Guidance	Marks
06	1	**Marks are for AO2 (application)** Marking guidance for examiners • Award marks for working out until an incorrect step has been made. • If, in any one step, a candidate is simplifying different parts of an expression simultaneously award all relevant marks for this multiple stage but don't award any further marks for working in any parts simplified incorrectly. Example, if the expression P.P.(P+Q) + P.P.1 was changed to P.(P+Q) + P.0, the candidate would get one mark for simplifying the first part to P.(P+Q) and could get further marks for correctly simplifying this part of the expression further but should not be awarded marks for simplifying the incorrectly changed part P.0 (ie to 0). Award up to **3 marks** for working. **1 mark per application** of a technique that produces a simplified expression. Of the 3 working marks **award at most 1 mark for correctly applying the Distributive Law** to expand or introduce brackets. **Note:** A simpler expression is one that is logically equivalent to the original expression but uses fewer logical operators. **1 mark** for final answer: $X \cdot Z + X \cdot Y + W \cdot Z$ or $X \cdot (Z + Y) + W \cdot Z$ **Example working 1:** $\overline{W} \cdot X \cdot Z + W \cdot Z + X \cdot Y \cdot \overline{Z} + \overline{W} \cdot X \cdot Y \cdot 1$ $\overline{W} \cdot X \cdot Z + W \cdot Z + X \cdot Y \cdot \overline{Z} + \overline{W} \cdot X \cdot Y$ Identity $A.1 = A$ $Z \cdot (\overline{W} \cdot X + W) + X \cdot Y \cdot \overline{Z} + \overline{W} \cdot X \cdot Y$ Distributive, put into brackets $Z \cdot (X + W) + X \cdot Y \cdot \overline{Z} + \overline{W} \cdot X \cdot Y$ $\overline{A}.B + A = B + A$ $X \cdot Z + W \cdot Z + X \cdot Y \cdot \overline{Z} + \overline{W} \cdot X \cdot Y$ Distributive, expand brackets $X \cdot \left(Z + Y \cdot \overline{Z}\right) + W \cdot Z + \overline{W} \cdot X \cdot Y$ Distributive, put into brackets $X \cdot (Z + Y) + W \cdot Z + \overline{W} \cdot X \cdot Y$ $\overline{A}.B + A = B + A$ $X \cdot Z + X \cdot Y + W \cdot Z + \overline{W} \cdot X \cdot Y$ Distributive, expand brackets $X \cdot Z + X \cdot Y \cdot \left(1 + \overline{W}\right) + W \cdot Z$ Distributive $X \cdot Z + X \cdot Y + W \cdot Z$ Identity $1 + A = A$ $X \cdot (Z + Y) + W \cdot Z$ (optional step)	4

Example working 2 :

$\bar{W}.X.Z+W.Z+X.Y.\bar{Z}+\bar{W}.X.Y.1$	
$\bar{W}.X.Z+W.Z+X.Y.\bar{Z}+\bar{W}.X.Y$	Identity A.1 = A
$Z.(\bar{W}.X+W) + X.Y.\bar{Z}+\bar{W}.X.Y$	Distributive, put into brackets
$Z.(X+W) + X.Y.\bar{Z}+\bar{W}.X.Y$	Identity $\bar{A}.B + A = B + A$
$Z.X + Z.W + X.Y.\bar{Z}+\bar{W}.X.Y$	Distribution, expand brackets
$Z.W + Z.X + X.Y.\bar{Z}+\bar{W}.X.Y$	Re-arrange terms
$Z.W+ X(Z+\bar{Z}.Y) + \bar{W}.X.Y$	Distribution, put into brackets
$Z.W+ X(Y + Z) + \bar{W}.X.Y$	Identity $\bar{A}.B + A = B + A$
$Z.W + X.Y + X.Z + \bar{W}.X.Y$	Distribution, expand brackets
$X.Z + Z.W + X.Y + \bar{W}.X.Y$	Re-arrange terms
$X.Z + Z.W + X.Y$	Identity A + A.B = A

Question			Marks
7	1	**Mark is for AO2 (analyse)** (runtime) error will occur if the following code is executed when square (being checked) does not contain a piece // it is necessary to check there is a piece in the square (before checking the type of the piece);	1
7	2	**Mark is for AO2 (apply)** `NOT Player1HasMirza OR NOT Player2HasMirza`; **R.** `Player1HasMirza = False OR Player2HasMirza = False`	1

08	**1**	**All marks AO1 (understanding)** If input A is 0 then NOT A will be 1 and if A is 1 then NOT A will be 0 // one of the inputs to the AND operator will always be 0 // the inputs can only be 0,1 or 1,0; **NE.** if only expressed one way around eg if A is 0 then NOT A is 1 **NE.** NOT A is always the opposite of A unless clarified that possible values are 0/1 **NE.** if only presented as a truth table **A.** on/off, true/false for 1/0 An AND gate only outputs 1 if both inputs are 1 // an AND gate always outputs 0 if one of its inputs is 0 // when inputs to AND are 1 and 0 then output is 0;	**2**

08	2	**All marks AO2 (apply)** **Marking guidance for examiners** • Award marks for working out until an incorrect step has been made. • If, in any one step, a candidate is simplifying different parts of an expression simultaneously award all relevant marks for this multiple stage but don't award any further marks for working in any parts simplified incorrectly. For example, if the expression P.P.(P+Q) + P.P.1 was changed to P.(P+Q)+P.0, the candidate would get one mark for simplifying the first part to P.(P+Q) and could get further marks for correctly simplifying this part of the expression further but should not be awarded marks for simplifying the incorrectly changed part P.0 (ie to 0) **1 mark** for final answer: A + B **Max 3** for working. Award up to two marks for applying each one of the three techniques (one mark per application): • a successful application of De Morgan's Law (and any associated cancellation of NOTs) that produces a simpler expression. • applying an identity other than cancelling NOTs that produces a simpler expression. • successfully expanding brackets. **Note:** A simpler expression is one that is logically equivalent to the original expression but uses fewer logical operators. **Max 3** if correct final answer but any incorrect working **Example Solution (1)** $\overline{\overline{\overline{\overline{B}} \cdot A} \cdot \overline{B}} + A \cdot B$ $\overline{(B + \overline{A}) \cdot \overline{B}} + A \cdot B$ — By De Morgan's law $\overline{B \cdot \overline{B} + \overline{A} \cdot \overline{B}} + A \cdot B$ — Expansion of brackets $\overline{0 + \overline{A} \cdot \overline{B}} + A \cdot B$ — By identity $X \cdot \overline{X} = 0$ $\overline{\overline{A} \cdot \overline{B}} + A \cdot B$ — By identity $X + 0 = X$ $A + B + A \cdot B$ — By De Morgan's law $A + B$ — By redundancy theorem $X + X \cdot Y = X$	**4**

Example Solution (2)

$\overline{\overline{\overline{B} \,.\, A} \,.\, \overline{B}} + A \,.\, B$	
$\overline{(B + \overline{A}) \,.\, \overline{B}} + A \,.\, B$	By De Morgan's law
$\overline{B + \overline{A}} + B + A \,.\, B$	By De Morgan's law
$\overline{B + \overline{A}} + B$	By redundancy theorem $X + X \cdot Y = X$
$\overline{B} \,.\, A + B$	By De Morgan's law
$(B + \overline{B}) \,.\, (A + B)$	Put into brackets
$(1 \,.\, (A + B)$	By identity $X + \overline{X} = 1$
$A + B$	By identity $X \,.1 = X$

Example Solution (3)

$\overline{\overline{\overline{B} \,.\, A} \,.\, \overline{B}} + A \,.\, B$	
$\overline{B} \,.\, A + B + A \,.\, B$	By De Morgan's law
$A.\,(\overline{B} + B) + B$	Identify common factor A
$A \,.1 + B$	By identity $X + \overline{X} = 1$
$A + B$	By identity $X \,.1 = X$

9	**1**	**4 marks for AO2 (apply)** **Marking guidance for examiners:** • award marks for working out until an incorrect step has been made • ignore missing steps from the example solutions, as long as the jumps between steps are logically correct • if, in any one step, a candidate is simplifying different parts of an expression simultaneously award all relevant marks for this multiple stage but don't award any further marks for working in any parts simplified incorrectly. For example, if the expression P.P.(P+Q) + P.P.1 was changed to P.(P+Q)+P.0, the candidate would get one mark for simplifying the first part to P.(P+Q) and could get further marks for correctly simplifying this part of the expression further but should not be awarded marks for simplifying the incorrectly changed part P.0 (ie to 0). **1 mark** for final answer: $A \cdot B$ **Max 3** for working. Award up to three marks for applying each one of the three techniques (one mark per application): • a successful application of De Morgan's Law (and any associated cancellation of NOTs) that produces a simpler expression; • applying an identity other than cancelling NOTs that produces a simpler expression; • successfully expanding brackets; **Note:** A simpler expression is one that is logically equivalent to the original expression but uses fewer logical operators. **Example Solution (1)** $\overline{\overline{A \cdot (A+1)} \cdot \overline{B}} \cdot \overline{\overline{A} + \overline{B+0}}$ $\overline{\overline{A \cdot 1} \cdot \overline{B}} \cdot \overline{\overline{A} + \overline{B+0}}$ By $X+1=1$ $\overline{\overline{A} \cdot \overline{B}} \cdot \overline{\overline{A} + \overline{B+0}}$ By $X \cdot 1 = X$ $\overline{\overline{A} \cdot \overline{B}} \cdot \overline{\overline{A} + \overline{B}}$ By $X+0=X$ $(A+B) \cdot \overline{\overline{A} + \overline{B}}$ Application of De Morgan $(A+B) \cdot (A \cdot B)$ Application of De Morgan $A \cdot A \cdot B + B \cdot A \cdot B$ Expansion of brackets $A \cdot B + B \cdot A \cdot B$ By $X \cdot X = X$ $A \cdot B + B \cdot A$ By $X \cdot X = X$ $A \cdot B$ By $X + X = X$ **Example Solution (2)** $\overline{\overline{A \cdot (A+1)} \cdot \overline{B}} \cdot \overline{\overline{A} + \overline{B+0}}$ $\overline{\overline{A \cdot 1} \cdot \overline{B}} \cdot \overline{\overline{A} + \overline{B+0}}$ By $X+1=1$ $\overline{\overline{A} \cdot \overline{B}} \cdot \overline{\overline{A} + \overline{B+0}}$ By $X \cdot 1 = X$ $\overline{\overline{A} \cdot \overline{B}} \cdot \overline{\overline{A} + \overline{B}}$ By $X+0=X$ $\overline{\overline{A} \cdot \overline{B}} + \overline{\overline{A}} + \overline{\overline{B}}$ Application of De Morgan $\overline{\overline{A} + \overline{B}}$ By $X + X \cdot Y = X$ $A \cdot B$ Application of De Morgan	**4**

Example Solution (3)

$\overline{\overline{A \cdot (A + 1)} \cdot \overline{B}} \cdot \overline{\overline{A} + \overline{B + 0}}$	
$\overline{A \cdot (A + 1)} \cdot \overline{B} + \overline{A} + \overline{B + 0}$	Application of De Morgan
$\overline{A \cdot A} \cdot \overline{B} + \overline{A} + \overline{B + 0}$	By $X + 1 = 1$
$\overline{A} \cdot \overline{B} + \overline{A} + \overline{B + 0}$	By $X \cdot X = X$
$\overline{A} + \overline{B + 0}$	By $X + X \cdot Y = X$
$\overline{A} + \overline{B}$	By $X + 0 = X$
$A \cdot B$	Application of De Morgan

Question			Marks
10	1	**All marks AO2 (apply)** Simplification of the two sub-expressions $\overline{\overline{A} + B \cdot C + B \cdot \overline{C}}$ and $C \cdot \left(A + \overline{A} \cdot (B + 1)\right)$ should be marked independently. Stop awarding marks for a sub-expression as soon as a mistake has been made in that sub-expression, but continue to award marks for simplifying the other sub-expression. **Marking guidance for examiners:** • award marks for working out until an incorrect step has been made • ignore missing steps from the example solutions, as long as the jumps between steps are logically correct • if, in any one step, a candidate is simplifying different parts of an expression simultaneously award all relevant marks for this multiple stage but don't award any further marks for working in any parts simplified incorrectly. For example, if the expression P.P.(P+Q) + P.P.1 was changed to P.(P+Q)+P.0, the candidate would get one mark for simplifying the first part to P.(P+Q) and could get further marks for correctly simplifying this part of the expression further but should not be awarded marks for simplifying the incorrectly changed part P.0 (ie to 0). **1 mark** for final answer: $A \cdot \overline{B} + C$ **Max 3** for working. Award up to three marks for applying each one of the three techniques (one mark per application): • a successful application of De Morgan's Law (and any associated cancellation of NOTs) that produces a simpler expression • applying an identity other than cancelling NOTs that produces a simpler expression • successfully putting terms into brackets • successfully expanding brackets • successfully using the distributive law. **Note:** A simpler expression is one that is logically equivalent to the original expression but uses fewer logical operators. **Max 3 overall if any working is incorrect**	**4**

Example Solution (1)

$\overline{\overline{\mathrm{A}} + \mathrm{B} \cdot \mathrm{C} + \mathrm{B} \cdot \overline{\mathrm{C}}} + \mathrm{C} \cdot \left(\mathrm{A} + \overline{\mathrm{A}} \cdot (\mathrm{B} + 1)\right)$	
$\overline{\overline{\mathrm{A}} + \mathrm{B} \cdot \mathrm{C} + \mathrm{B} \cdot \overline{\mathrm{C}}} + \mathrm{C} \cdot (\mathrm{A} + \overline{\mathrm{A}} \cdot 1)$	By $X + 1 = 1$
$\overline{\overline{\mathrm{A}} + \mathrm{B} \cdot \mathrm{C} + \mathrm{B} \cdot \overline{\mathrm{C}}} + \mathrm{C} \cdot (\mathrm{A} + \overline{\mathrm{A}})$	By $X \cdot 1 = X$
$\overline{\overline{\mathrm{A}} + \mathrm{B} \cdot \mathrm{C} + \mathrm{B} \cdot \overline{\mathrm{C}}} + \mathrm{C} \cdot 1$	By $X + \bar{X} = 1$
$\overline{\overline{\mathrm{A}} + \mathrm{B} \cdot \mathrm{C} + \mathrm{B} \cdot \overline{\mathrm{C}}} + \mathrm{C}$	By $X \cdot 1 = X$
$\overline{\overline{\mathrm{A}} + \mathrm{B} \cdot (\mathrm{C} + \overline{\mathrm{C}})} + \mathrm{C}$	Put into brackets
$\overline{\overline{\mathrm{A}} + \mathrm{B} \cdot 1} + \mathrm{C}$	By $X + \bar{X} = 1$
$\overline{\overline{\mathrm{A}} + \mathrm{B}} + \mathrm{C}$	By $X \cdot 1 = X$
$\mathrm{A} \cdot \overline{\mathrm{B}} + \mathrm{C}$	Application of De Morgan

Example Solution (2)

$\overline{\overline{\overline{\mathrm{A}} + \mathrm{B} \cdot \mathrm{C} + \mathrm{B} \cdot \overline{\mathrm{C}}} + \mathrm{C} \cdot (\mathrm{A} + \overline{\mathrm{A}} \cdot (\mathrm{B} + 1))}$	
$\overline{(\overline{\mathrm{A}} + \mathrm{B} \cdot \mathrm{C} + \mathrm{B} \cdot \overline{\mathrm{C}}) \cdot \overline{\mathrm{C} \cdot \left(\mathrm{A} + \overline{\mathrm{A}} \cdot (\mathrm{B} + 1)\right)}}$	Application of De Morgan
$\overline{(\overline{\mathrm{A}} + \mathrm{B} \cdot (\mathrm{C} + \overline{\mathrm{C}})) \cdot \overline{\mathrm{C} \cdot \left(\mathrm{A} + \overline{\mathrm{A}} \cdot (\mathrm{B} + 1)\right)}}$	Put into brackets
$\overline{(\overline{\mathrm{A}} + \mathrm{B} \cdot (1)) \cdot \overline{\mathrm{C} \cdot \left(\mathrm{A} + \overline{\mathrm{A}} \cdot (\mathrm{B} + 1)\right)}}$	By $X + \bar{X} = 1$
$\overline{(\overline{\mathrm{A}} + \mathrm{B}) \cdot \overline{\mathrm{C} \cdot \left(\mathrm{A} + \overline{\mathrm{A}} \cdot (\mathrm{B} + 1)\right)}}$	By $X \cdot 1 = X$
$\overline{(\overline{\mathrm{A}} + \mathrm{B}) \cdot \overline{\mathrm{C} \cdot (\mathrm{A} + \overline{\mathrm{A}} \cdot 1)}}$	By $X + 1 = 1$
$\overline{(\overline{\mathrm{A}} + \mathrm{B}) \cdot \overline{\mathrm{C} \cdot (\mathrm{A} + \overline{\mathrm{A}})}}$	By $X \cdot 1 = X$
$\overline{(\overline{\mathrm{A}} + \mathrm{B}) \cdot \overline{\mathrm{C} \cdot (1)}}$	By $X + \bar{X} = 1$
$\overline{(\overline{\mathrm{A}} + \mathrm{B}) \cdot \overline{\mathrm{C}}}$	By $X \cdot 1 = X$
$\overline{\overline{\mathrm{A}} + \mathrm{B}} + \mathrm{C}$	Application of De Morgan
$\mathrm{A} \cdot \overline{\mathrm{B}} + \mathrm{C}$	Application of De Morgan

Example Solution (3)

$\overline{\overline{A} + B \cdot C + B \cdot \overline{C}} + C \cdot (A + \overline{A} \cdot (B + 1))$	
$\overline{\overline{A} + B \cdot C + B \cdot \overline{C}} + C \cdot (A + \overline{A} \cdot 1)$	By $X + 1 = 1$
$\overline{\overline{A} + B \cdot C + B \cdot \overline{C}} + C \cdot (A + \overline{A})$	By $X \cdot 1 = X$
$\overline{\overline{A} + B \cdot C + B \cdot \overline{C}} + C \cdot 1$	By $X + \overline{X} = 1$
$\overline{\overline{A} + B \cdot C + B \cdot \overline{C}} + C$	By $X \cdot 1 = X$
$(\overline{\overline{A} + B \cdot C}) \cdot \overline{B \cdot \overline{C}} + C$	Application of De Morgan
$(\overline{\overline{A} + B \cdot C}) \cdot (\overline{B} + C) + C$	Application of De Morgan
$(A \cdot \overline{B \cdot C}) \cdot (\overline{B} + C) + C$	Application of De Morgan
$A \cdot (\overline{B} + \overline{C}) \cdot (\overline{B} + C) + C$	Application of De Morgan
$A \cdot \overline{B} \cdot \overline{B} + A \cdot \overline{C} \cdot \overline{B} + A \cdot \overline{B} \cdot C + A \cdot \overline{C} \cdot C + C$	Expand Brackets
$A \cdot \overline{B} + A \cdot \overline{C} \cdot \overline{B} + C$	By $C +$ any term with $C = C$ / distributive law
$A \cdot \overline{B} + C$	By distributive law

Qu	Pt	Marking guidance	Total marks
11	1	**All marks AO2 (apply)** **Marking guidance for examiners** • Award marks for working out until an incorrect step has been made. • Ignore missing steps from the example solutions, as long as the jumps between steps are logically correct. • If, in any one step, a candidate is simplifying different parts of an expression simultaneously and makes an error, award marks for the correctly simplified part(s) and then stop marking. **1 mark** for final answer: A **3 marks** for working. Award up to **three marks** for applying each one of the three techniques (**one mark** per application, multiple marks can be awarded for using the same technique more than once): • a successful application of De Morgan's Law (and any associated cancellation of NOTs) that produces a simpler expression – award 2 marks if De Morgan's Law applied twice simultaneously • applying an identity other than cancelling NOTs that produces a simpler expression • successfully expanding brackets // factorising. **Note:** A simpler expression is one that is logically equivalent to the original expression but uses fewer logical operators. **Max 2** for working if there is no successful application of De Morgan. **Max 3** overall if any incorrect working **Example Solution 1** $\mathrm{A} \cdot \overline{\mathrm{B}} + \mathrm{B} \cdot (\overline{\overline{\mathrm{A}} + (\overline{\mathrm{B}} \cdot \mathrm{C})})$ $\mathrm{A} \cdot \overline{\mathrm{B}} + \mathrm{B} \cdot \mathrm{A} \cdot \overline{\overline{\mathrm{B}} \cdot \mathrm{C}}$ Application of De Morgan $\mathrm{A} \cdot (\overline{\mathrm{B}} + \mathrm{B} \cdot \overline{\overline{\mathrm{B}} \cdot \mathrm{C}})$ Factorising $\mathrm{A} \cdot (\overline{\mathrm{B}} + \mathrm{B} \cdot (\mathrm{B} + \overline{\mathrm{C}}))$ Application of De Morgan $\mathrm{A} \cdot (\overline{\mathrm{B}} + \mathrm{B} \cdot \mathrm{B} + \mathrm{B} \cdot \overline{\mathrm{C}})$ Expand brackets $\mathrm{A} \cdot (\overline{\mathrm{B}} + \mathrm{B} + \mathrm{B} \cdot \overline{\mathrm{C}})$ By $X \cdot X = X$ $\mathrm{A} \cdot (1 + \mathrm{B} \cdot \overline{\mathrm{C}})$ By $X + \bar{X} = 1$ $\mathrm{A} \cdot 1$ By $X + 1 = 1$ A By $X \cdot 1 = X$	4

Example Solution 2

$A \cdot \overline{B} + B \cdot (\overline{\overline{A} + (\overline{B} \cdot C)})$	
$A \cdot \overline{B} + B \cdot (\overline{\overline{A} + \overline{(B + \overline{C})}})$	Application of De Morgan
$A \cdot \overline{B} + B \cdot A \cdot (B + \overline{C})$	Application of De Morgan
$A \cdot \overline{B} + B \cdot A \cdot B + B \cdot A \cdot \overline{C}$	Expand brackets
$A \cdot \overline{B} + A \cdot B + B \cdot A \cdot \overline{C}$	By $X \cdot X = X$
$A \cdot (\overline{B} + B) + B \cdot A \cdot \overline{C}$	Factorising partially
$A \cdot 1 + B \cdot A \cdot \overline{C}$	By $X + \overline{X} = 1$
$A + B \cdot A \cdot \overline{C}$	By $X \cdot 1 = X$
A	By $X + (X \cdot Y) = X$

Example Solution 3

$A \cdot \overline{B} + B \cdot (\overline{\overline{A} + (\overline{B} \cdot C)})$	
$A \cdot \overline{B} + B \cdot (\overline{\overline{A} + \overline{(B + \overline{C})}})$	Application of De Morgan
$A \cdot \overline{B} + B \cdot A \cdot (B + \overline{C})$	Application of De Morgan
$A \cdot (\overline{B} + B \cdot (B + \overline{C}))$	Factorising
$A \cdot (\overline{B} + B \cdot B + B \cdot \overline{C})$	Expanding brackets
$A \cdot (\overline{B} + B + B \cdot \overline{C})$	By $X \cdot X = X$
$A \cdot (1 + B \cdot \overline{C})$	By $X + \overline{X} = 1$
$A \cdot 1$	By $X + 1 = 1$
A	By $X \cdot 1 = X$

Example Solution 4

$A \cdot \overline{B} + B \cdot (\overline{\overline{A} + (\overline{B} \cdot C)})$	
$A \cdot \overline{B} + B \cdot (\overline{\overline{A} + \overline{(B + \overline{C})}})$	Application of De Morgan
$A \cdot \overline{B} + B \cdot A \cdot (B + \overline{C})$	Application of De Morgan
$A \cdot \overline{B} + B \cdot A \cdot B + B \cdot A \cdot \overline{C}$	Expand brackets
$A \cdot \overline{B} + B \cdot A + B \cdot A \cdot \overline{C}$	By $X \cdot X = X$
$A \cdot \overline{B} + B \cdot A$	By $X + (X \cdot Y) = X$
$A \cdot (\overline{B} + B)$	Factorising
$A \cdot 1$	By $X + \overline{X} = 1$
A	By $X \cdot 1 = X$

Qu	Pt	Marking guidance	Total marks
12	1	**All marks AO2 (apply)** **Marking guidance for examiners** • Award marks for working out until an incorrect step has been made. • Ignore missing steps from the example solutions, as long as the jumps between steps are logically correct. • If, in any one step, a candidate is simplifying different parts of an expression simultaneously, award all relevant marks for this multiple stage but don't award any further marks for working in any parts simplified incorrectly. For example, if the expression P.P.(P+Q) + P.P.1 was changed to P.(P+Q)+P.0, the candidate would get one mark for simplifying the first part to P.(P+Q) and could get further marks for correctly simplifying this part of the expression further but should not be awarded marks for simplifying the incorrectly changed part P.0 (ie to 0). **1 mark** for final answer: $\mathrm{A} \oplus \mathrm{B}$ **A.** XOR instead of $\oplus$ **A.** $\overline{\mathrm{A}} \cdot \mathrm{B} + \mathrm{A} \cdot \overline{\mathrm{B}}$ **Max 3** for working. Award up to **three marks** for applying each one of the three techniques (**one mark** per application): • a successful application of De Morgan's Law (and any associated cancellation of NOTs) that produces a simpler expression • applying an identity other than cancelling NOTs that produces a simpler expression • successfully expanding brackets // factorising. **Max 2** for working if there is no successful application of De Morgan **Max 3** overall if any errors in working **Note:** A simpler expression is one that is logically equivalent to the original expression but uses fewer logical operators. **Example Solution (1)** $\overline{\mathrm{A}} \cdot (\mathrm{B} \cdot \mathrm{C} \cdot \mathrm{D} + \mathrm{B} \cdot \mathrm{C} \cdot \overline{\mathrm{D}} + \mathrm{B}) + \overline{\overline{\mathrm{A}} + \mathrm{B}}$ $\overline{\mathrm{A}} \cdot (\mathrm{B} \cdot \mathrm{C} \cdot (\mathrm{D} + \overline{\mathrm{D}}) + \mathrm{B}) + \overline{\overline{\mathrm{A}} + \mathrm{B}}$ Factorising $\overline{\mathrm{A}} \cdot (\mathrm{B} \cdot \mathrm{C} \cdot 1 + \mathrm{B}) + \overline{\overline{\mathrm{A}} + \mathrm{B}}$ By $X + \bar{X} = 1$ $\overline{\mathrm{A}} \cdot (\mathrm{B} \cdot \mathrm{C} + \mathrm{B}) + \overline{\overline{\mathrm{A}} + \mathrm{B}}$ By $X \cdot 1 = X$ $\overline{\mathrm{A}} \cdot \mathrm{B} + \overline{\overline{\mathrm{A}} + \mathrm{B}}$ By $X + X \cdot Y = X$ $\overline{\mathrm{A}} \cdot \mathrm{B} + \mathrm{A} \cdot \overline{\mathrm{B}}$ Application of De Morgan $\mathrm{A} \oplus \mathrm{B}$ Simplification to XOR	**4**

Example Solution (2)

$\overline{A} \cdot (B \cdot C \cdot D + B \cdot C \cdot \overline{D} + B) + \overline{\overline{A} + B}$	
$\overline{A} \cdot B \cdot C \cdot D + \overline{A} \cdot B \cdot C \cdot \overline{D} + \overline{A} \cdot B + \overline{\overline{A} + B}$	Expand brackets
$\overline{A} \cdot B \cdot C \cdot D + \overline{A} \cdot B \cdot C \cdot \overline{D} + \overline{A} \cdot B + A \cdot \overline{B}$	Application of De Morgan
$\overline{A} \cdot B \cdot C \cdot (D + \overline{D}) + \overline{A} \cdot B + A \cdot \overline{B}$	Factorising
$\overline{A} \cdot B \cdot C \cdot 1 + \overline{A} \cdot B + A \cdot \overline{B}$	By $X + \overline{X} = 1$
$\overline{A} \cdot B \cdot C + \overline{A} \cdot B + A \cdot \overline{B}$	By $X \cdot 1 = X$
$\overline{A} \cdot B + A \cdot \overline{B}$	By $X + X \cdot Y = X$
$A \oplus B$	Simplification to XOR

Example Solution (3)

$\overline{A} \cdot (B \cdot C \cdot D + B \cdot C \cdot \overline{D} + B) + \overline{\overline{A} + B}$	
$\overline{A} \cdot (B \cdot C \cdot D + B) + \overline{\overline{A} + B}$	By $X + X \cdot Y = X$ (where $X = B$ and $Y = C \cdot \overline{D}$)
$\overline{A} \cdot B + \overline{\overline{A} + B}$	By $X + X \cdot Y = X$ (where $X = B$ and $Y = C \cdot D$)
$\overline{A} \cdot B + A \cdot \overline{B}$	Application of De Morgan
$A \oplus B$	Simplification to XOR

Example Solution (4)

$\overline{A} \cdot (B \cdot C \cdot D + B \cdot C \cdot \overline{D} + B) + \overline{\overline{A} + B}$	
$\overline{A} \cdot B + \overline{\overline{A} + B}$	By $X + X \cdot Y = X$ – Award 2 marks as rule applied twice (where $X = B$ and $Y = C \cdot \overline{D}$ then $Y = C \cdot D$)
$\overline{A} \cdot B + A \cdot \overline{B}$	Application of De Morgan
$A \oplus B$	Simplification to XOR

Example Solution (5)

$\overline{A} \cdot (B \cdot C \cdot D + B \cdot C \cdot \overline{D} + B) + \overline{\overline{A} + B}$	
$\overline{A} \cdot (B \cdot (C \cdot D + C \cdot \overline{D} + 1)) + \overline{\overline{A} + B}$	Factorising
$\overline{A} \cdot (B \cdot 1) + \overline{\overline{A} + B}$	By $X + 1 = 1$
$\overline{A} \cdot B + \overline{\overline{A} + B}$	By $X \cdot 1 = X$
$\overline{A} \cdot B + A \cdot \overline{B}$	Application of De Morgan
$A \oplus B$	Simplification to XOR