1.4 DATA TYPES & STRUCTURES · 1.4.3

Simplifying Boolean & De Morgan's — Mark scheme

40 marks · spec 1.4.3(a)(c) · all identities verified

AO key: AO1 = knowledge · AO2 = application. Accept equivalent notation. Every simplification verified by truth-table equivalence.

Q	ANSWER	AO	MARKS

1	`X·0 = 0` · `X·1 = X` · `X·X = X` · `X·¬X = 0`
	`X+0 = X` · `X+1 = 1` · `X+X = X` · `X+¬X = 1`
	`¬(¬X) = X` · `X·(X+Y) = X` · `X+(X·Y) = X` · `X·(Y+Z) = X·Y + X·Z`
	1 mark per 1½ correct entries, max 8. (8)
		AO1	8

Q	ANSWER	AO	MARKS
2(a)	`¬(A · B) = ¬A + ¬B`. (1)	AO1	1
2(b)	`¬(A + B) = ¬A · ¬B`. (1)	AO1	1
2(c)	Break (or join) the bar over the whole expression AND swap each AND for an OR (and each OR for an AND), inverting each variable. (1)	AO1	1

Q	ANSWER	AO	MARKS
3(a)	`A` (since B + 1 = 1, and A · 1 = A). (1)	AO2	1
3(b)	`A · B` (De Morgan: ¬(¬A + ¬B) = A · B). (1)	AO2	1
3(c)	`A · B` (A·A·B = A·B and A·B·B = A·B; A·B + A·B = A·B). (1)	AO2	1
3(d)	`A + B`. (1)	AO2	1

Q	ANSWER	AO	MARKS
4(a)	`(A·¬B) + A·(B+C)` = A·¬B + A·B + A·C (distributive) (1) = A·(¬B + B) + A·C = A·1 + A·C = A + A·C (1) = **A** (absorption) (1). (3)	AO2	3
4(b)	`A·(A+B) + B` = A + B: A·(A+B) = A (absorption) (1) giving A + B (1); final answer **A + B** (1). (3)	AO2	3

<table>
<tr><th>Q</th><th>ANSWER</th><th>AO</th><th>MARKS</th></tr>
<tr><td>5</td><td>
<table>
<tr><th>A</th><th>B</th><th>¬A</th><th>¬A·B</th><th>A+(¬A·B)</th><th>A+B</th></tr>
<tr><td>0</td><td>0</td><td>1</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>0</td><td>1</td><td>1</td><td>1</td><td>1</td><td>1</td></tr>
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¬A column (1); ¬A·B column (1); A+(¬A·B) column (1); A+B column (1); both result columns identical (1); conclusion "equal / identical" (1). (6)
</td><td>AO2</td><td>6</td></tr>
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Q	ANSWER	AO	MARKS
6(a)	`F = A·¬B + A·(B+C)` = A·¬B + A·B + A·C (distributive) **(1)** = A + A·C **(1)** = **A** **(1)**. **(3)**	AO2	**3**
6(b)	Simplified expression is just `A` — output is connected straight to A, needing **0 gates** (a wire) **(1)**; correct/consistent circuit shown **(1)**. **(2)**	AO2	**2**
6(c)	Simplifying removes gates **(1)**; fewer gates = lower manufacturing cost / less power / less heat / faster / smaller chips, multiplied across millions of units **(1)**. **(2)**	AO2	**2**

Q	ANSWER	AO	MARKS
7(a)	`¬(A·B) · ¬(¬A + B)` : apply De Morgan to each → (¬A + ¬B)·(A·¬B) **(1)**; multiply out → ¬A·A·¬B + ¬B·A·¬B = 0 + A·¬B **(1)**; answer **A·¬B** **(1)**. **(3)**	AO2	**3**
7(b)	`(A+B)·(A+¬B)` = A + (B·¬B) (distributive: A + BC form) **(1)** = A + 0 **(1)** = **A** **(1)**. **(3)**	AO2	**3**

Total for worksheet: 40 marks