

1.

(a)(i) $\sim c \Rightarrow e$	B1
(ii) $(c \Rightarrow \sim e) \Leftrightarrow (\sim c \Rightarrow e)$ $\begin{array}{cccccc} 1 & 0 & 0 & 1 & 0 & 0 & 1 & 1 & 1 \\ \text{or} & 0 & 1 & 1 & 0 & 0 & 1 & 0 & 0 & 0 \end{array}$	M1 line of a TT A1 both propositions 1 or both 0 M1 an " \Rightarrow " correct A1 all OK
(b)(i) Circuit is $\sim x \vee y$. This is $x \Rightarrow y$. $\begin{array}{cc} 10 & 10 & 0 & 1 & 0 \\ 10 & 11 & 0 & 1 & 1 \\ 01 & 00 & 1 & 0 & 0 \\ 01 & 11 & 1 & 1 & 1 \end{array}$	B1 B4
(ii) $(\sim p \wedge \sim q) \Rightarrow r$	M1 implication noted A1
(iii) $(\sim p \wedge \sim q) \Rightarrow r$ is equivalent to $\sim r \Rightarrow \sim(\sim p \wedge \sim q)$	B1
But we have $\sim r$, so we have $\sim(\sim p \wedge \sim q)$.	B1
$\sim(\sim p \wedge \sim q)$ is equivalent to $p \vee q$	B1
But we have $\sim q$, so therefore p .	B1

2.

(i) Distances longer													B1		
(ii)															
	1	2	3	4	5	6		1	2	3	4	5	6		
1	∞	15	∞	∞	7	8		1	1	2	3	4	5	6	
2	15	∞	6	2	6	∞		2	1	2	3	4	5	6	not part of answer
3	∞	6	∞	3	∞	∞		3	1	2	3	4	5	6	
4	∞	2	3	∞	10	17		4	1	2	3	4	5	6	
5	7	6	∞	10	∞	8		5	1	2	3	4	5	6	
6	8	∞	∞	17	8	∞		6	1	2	3	4	5	6	
	1	2	3	4	5	6		1	2	3	4	5	6		
1	∞	15	∞	∞	7	8		1	1	2	3	4	5	6	
2	15	30	6	2	6	23		2	1	1	3	4	5	1	not part of answer
3	∞	6	∞	3	∞	∞		3	1	2	3	4	5	6	
4	∞	2	3	∞	10	17		4	1	2	3	4	5	6	
5	7	6	∞	10	14	8		5	1	2	3	4	1	6	
6	8	23	∞	17	8	16		6	1	1	3	4	5	1	
	1	2	3	4	5	6		1	2	3	4	5	6		
1	30	15	21	17	7	8		1	2	2	2	2	5	6	M1 30 in top left
2	15	30	6	2	6	23		2	1	1	3	4	5	1	A1 times
3	21	6	12	3	12	29		3	2	2	2	4	2	2	A1 6 to 3 route = 1
4	17	2	3	4	8	17		4	2	2	3	2	2	6	A1 rest of route
5	7	6	12	8	12	8		5	1	2	2	2	2	6	
6	8	23	29	17	8	16		6	1	1	1	4	5	1	
	1	2	3	4	5	6		1	2	3	4	5	6		
1	30	15	21	17	7	8		1	2	2	2	2	5	6	not part of answer
2	15	12	6	2	6	23		2	1	3	3	4	5	1	
3	21	6	12	3	12	29		3	2	2	2	4	2	2	
4	17	2	3	4	8	17		4	2	2	3	2	2	6	
5	7	6	12	8	12	8		5	1	2	2	2	2	6	
6	8	23	29	17	8	16		6	1	1	1	4	5	1	
	1	2	3	4	5	6		1	2	3	4	5	6		
1	30	15	20	17	7	8		1	2	2	2	2	5	6	not part of answer
2	15	4	5	2	6	19		2	1	4	4	4	5	4	
3	20	5	6	3	11	20		3	4	4	4	4	4	4	
4	17	2	3	4	8	17		4	2	2	3	2	2	6	
5	7	6	11	8	12	8		5	1	2	2	2	2	6	
6	8	19	20	17	8	16		6	1	4	4	4	5	1	
	1	2	3	4	5	6		1	2	3	4	5	6		
1	14	13	18	15	7	8		1	5	5	5	5	5	6	not part of answer
2	13	4	5	2	6	14		2	5	4	4	4	5	5	
3	18	5	6	3	11	19		3	4	4	4	4	4	4	
4	15	2	3	4	8	16		4	2	2	3	2	2	2	
5	7	6	11	8	12	8		5	1	2	2	2	2	6	
6	8	14	19	16	8	16		6	1	5	5	5	5	1	
	1	2	3	4	5	6		1	2	3	4	5	6		
1	14	13	18	15	7	8		1	5	5	5	5	5	6	not part of answer
2	13	4	5	2	6	14		2	5	4	4	4	5	5	
3	18	5	6	3	11	19		3	4	4	4	4	4	4	
4	15	2	3	4	8	16		4	2	2	3	2	2	2	
5	7	6	11	8	12	8		5	1	2	2	2	2	6	
6	8	14	19	16	8	16		6	1	5	5	5	5	1	

<p>(iii) cont</p> <p>It has found all shortest times and corresponding routes. Shortest time from x to y is in x row and y column of time matrix.</p> <p>For route look in x row and y column of route matrix. This gives first vertex “en route”. Repeat, looking in row corresponding to the current “en route” vertex and the y column, until the “en route” vertex is y.</p> <p>Shortest time from 3 to 6 is 19. Corresponding route is 3 to 4 to 2 to 5 to 6.</p>	<p>B1 B1</p> <p>B1</p> <p>B1</p> <p>B1</p>
<p>(iv) On time matrix – 1(7)5(6)2(2)4(3)3(19)6(8)1 so 45 From route matrix – 1 5 2 4 3 4 2 5 6 1</p>	<p>B1</p> <p>B1</p>
<p>(v) Lower bound = $7 + 8 + 19 = 34$</p>	<p>M1</p> <p>A1 7 + 8</p> <p>A1 19</p>
<p>(vi) $82 + 8 = 90$ minutes</p>	<p>B1</p>

3.

<p>(i) & (ii)</p> <p>Retire at 65, EMV = 459375</p>	<p>M1 3-way split A1 choice node</p> <p>M1 2-way splits A1 chance nodes</p> <p>B1 pension calculations M1 (income + pension) × time A1 retire at 59 A1 retire at 60 A1 retire at 65</p> <p>M1 EMV's A1√</p> <p>M1 choice A1√</p>
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<p>(iii) p's (in order) $\frac{1}{2}$ 0 $\frac{6}{11}$ $\frac{1}{11}$ $\frac{17}{22}$ (given) $\frac{6}{11}$</p> <p>Retire at 59.</p>	<p>M1 A1</p> <p>M1 final utilites A1 cao</p> <p>M1 expecteds A1 \sqrt</p> <p>B1 choice</p>
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4.

<p>(i) Max $180x + 90y + 110z$ st $2x + 5y + 3z \leq 30$ $4x + y + 2z \leq 24$</p> <p>(ii)</p> <table border="1"> <thead> <tr> <th>P</th> <th>x</th> <th>y</th> <th>z</th> <th>s1</th> <th>s2</th> <th>RHS</th> </tr> </thead> <tbody> <tr> <td>1</td> <td>-180</td> <td>-90</td> <td>-110</td> <td>0</td> <td>0</td> <td>0</td> </tr> <tr> <td>0</td> <td>2</td> <td>5</td> <td>3</td> <td>1</td> <td>0</td> <td>30</td> </tr> <tr> <td>0</td> <td>4</td> <td>1</td> <td>2</td> <td>0</td> <td>1</td> <td>24</td> </tr> <tr> <td>1</td> <td>0</td> <td>-45</td> <td>-20</td> <td>0</td> <td>45</td> <td>1080</td> </tr> <tr> <td>0</td> <td>0</td> <td>4.5</td> <td>2</td> <td>1</td> <td>-0.5</td> <td>18</td> </tr> <tr> <td>0</td> <td>1</td> <td>0.25</td> <td>0.5</td> <td>0</td> <td>0.25</td> <td>6</td> </tr> <tr> <td>1</td> <td>0</td> <td>0</td> <td>0</td> <td>10</td> <td>40</td> <td>1260</td> </tr> <tr> <td>0</td> <td>0</td> <td>1</td> <td>4/9</td> <td>2/9</td> <td>-1/9</td> <td>4</td> </tr> <tr> <td>0</td> <td>1</td> <td>0</td> <td>7/18</td> <td>-1/18</td> <td>5/18</td> <td>5</td> </tr> </tbody> </table> <p>Identification of basic variables + values</p> <p>(iii) Over two weeks ($x = 3$ and $z = 18$)</p> <p>(iv) Degeneracy (technical term not required) – objective planes are parallel to boundary line.</p> <p>(v)</p> <table border="1"> <thead> <tr> <th>A</th> <th>P</th> <th>x</th> <th>y</th> <th>z</th> <th>s1</th> <th>s2</th> <th>s3</th> <th>s4</th> <th>a</th> <th>RHS</th> </tr> </thead> <tbody> <tr> <td>1</td> <td>0</td> <td>1</td> <td>1</td> <td>0</td> <td>0</td> <td>0</td> <td>0</td> <td>-1</td> <td>0</td> <td>7</td> </tr> <tr> <td>0</td> <td>1</td> <td>-180</td> <td>-90</td> <td>-110</td> <td>0</td> <td>0</td> <td>0</td> <td>0</td> <td>0</td> <td>0</td> </tr> <tr> <td>0</td> <td>0</td> <td>2</td> <td>5</td> <td>3</td> <td>1</td> <td>0</td> <td>0</td> <td>0</td> <td>0</td> <td>30</td> </tr> <tr> <td>0</td> <td>0</td> <td>4</td> <td>1</td> <td>2</td> <td>0</td> <td>1</td> <td>0</td> <td>0</td> <td>0</td> <td>24</td> </tr> <tr> <td>0</td> <td>0</td> <td>1</td> <td>1</td> <td>0</td> <td>0</td> <td>0</td> <td>1</td> <td>0</td> <td>0</td> <td>7</td> </tr> <tr> <td>0</td> <td>0</td> <td>1</td> <td>1</td> <td>0</td> <td>0</td> <td>0</td> <td>0</td> <td>-1</td> <td>1</td> <td>7</td> </tr> </tbody> </table> <p>or</p> <table border="1"> <thead> <tr> <th>P</th> <th>x</th> <th>y</th> <th>z</th> <th>s1</th> <th>s2</th> <th>s3</th> <th>s4</th> <th>a</th> <th>RHS</th> </tr> </thead> <tbody> <tr> <td>1</td> <td>-M-180</td> <td>-M-90</td> <td>-110</td> <td>0</td> <td>0</td> <td></td> <td>M</td> <td>0</td> <td>-7M</td> </tr> <tr> <td>0</td> <td>2</td> <td>5</td> <td>3</td> <td>1</td> <td>0</td> <td>0</td> <td>0</td> <td>0</td> <td>30</td> </tr> <tr> <td>0</td> <td>4</td> <td>1</td> <td>2</td> <td>0</td> <td>1</td> <td>0</td> <td>0</td> <td>0</td> <td>24</td> </tr> <tr> <td>0</td> <td>1</td> <td>1</td> <td>0</td> <td>0</td> <td>0</td> <td>1</td> <td>0</td> <td>0</td> <td>7</td> </tr> <tr> <td>0</td> <td>1</td> <td>1</td> <td>0</td> <td>0</td> <td>0</td> <td>0</td> <td>-1</td> <td>1</td> <td>7</td> </tr> </tbody> </table> <p>(vi) Point is on the line – gives £1260 profit</p>	P	x	y	z	s1	s2	RHS	1	-180	-90	-110	0	0	0	0	2	5	3	1	0	30	0	4	1	2	0	1	24	1	0	-45	-20	0	45	1080	0	0	4.5	2	1	-0.5	18	0	1	0.25	0.5	0	0.25	6	1	0	0	0	10	40	1260	0	0	1	4/9	2/9	-1/9	4	0	1	0	7/18	-1/18	5/18	5	A	P	x	y	z	s1	s2	s3	s4	a	RHS	1	0	1	1	0	0	0	0	-1	0	7	0	1	-180	-90	-110	0	0	0	0	0	0	0	0	2	5	3	1	0	0	0	0	30	0	0	4	1	2	0	1	0	0	0	24	0	0	1	1	0	0	0	1	0	0	7	0	0	1	1	0	0	0	0	-1	1	7	P	x	y	z	s1	s2	s3	s4	a	RHS	1	-M-180	-M-90	-110	0	0		M	0	-7M	0	2	5	3	1	0	0	0	0	30	0	4	1	2	0	1	0	0	0	24	0	1	1	0	0	0	1	0	0	7	0	1	1	0	0	0	0	-1	1	7	<p>B1 B1 B1</p> <p>M1 initial tableau A1</p> <p>M1 first iteration A1</p> <p>M1 second iteration A1</p> <p>B1 B1</p> <p>B1</p> <p>B1 same obj value B1 line of solutions</p> <p>B1 = $\rightarrow \leq + \geq$ B1 \leq row B1 \geq row B1 new objective B1 minimise A or</p> <p>B1 = $\rightarrow \leq + \geq$ B1 \leq row B1 \geq row B1 new objective B1 maximise P</p> <p>B1 (either)</p>
P	x	y	z	s1	s2	RHS																																																																																																																																																																																																										
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