

Mark Scheme (Results)

June 2011

GCE Decision D2 (6690) Paper 1

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June 2011

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EDEXCEL GCE MATHEMATICS

General Instructions for Marking

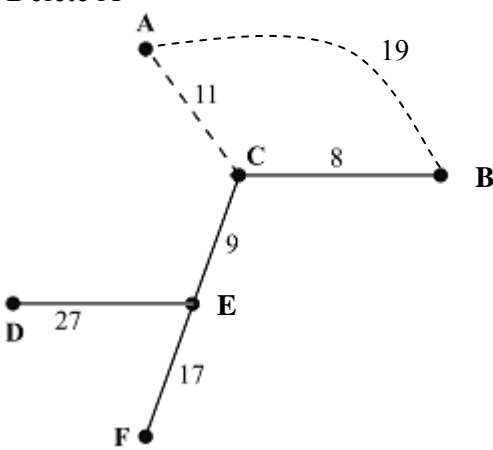
1. The total number of marks for the paper is 75.
2. The Edexcel Mathematics mark schemes use the following types of marks:
 - **M** marks: method marks are awarded for 'knowing a method and attempting to apply it', unless otherwise indicated.
 - **A** marks: Accuracy marks can only be awarded if the relevant method (M) marks have been earned.
 - **B** marks are unconditional accuracy marks (independent of M marks)
 - Marks should not be subdivided.

3. Abbreviations

These are some of the traditional marking abbreviations that will appear in the mark schemes and can be used if you are using the annotation facility on ePEN.

- bod – benefit of doubt
- ft – follow through
- the symbol \checkmark will be used for correct ft
- cao – correct answer only
- cso - correct solution only. There must be no errors in this part of the question to obtain this mark
- isw – ignore subsequent working
- awrt – answers which round to
- SC: special case
- oe – or equivalent (and appropriate)
- dep – dependent
- indep – independent
- dp decimal places
- sf significant figures
- * The answer is printed on the paper
- \square The second mark is dependent on gaining the first mark

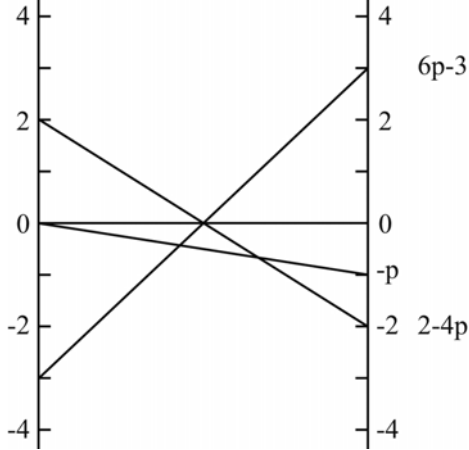
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Decision Mathematics D2 6690
Mark Scheme

Question Number	Scheme	Marks																																																	
<p>1. (a)</p>	<table border="1" style="margin-left: auto; margin-right: auto;"> <thead> <tr> <th></th> <th>A</th> <th>B</th> <th>C</th> <th>D</th> <th>E</th> <th>F</th> </tr> </thead> <tbody> <tr> <th>A</th> <td>-</td> <td>19</td> <td>11</td> <td>23</td> <td>20</td> <td>37</td> </tr> <tr> <th>B</th> <td>19</td> <td>-</td> <td>8</td> <td>42</td> <td>17</td> <td>32</td> </tr> <tr> <th>C</th> <td>11</td> <td>8</td> <td>-</td> <td>34</td> <td>9</td> <td>26</td> </tr> <tr> <th>D</th> <td>23</td> <td>42</td> <td>34</td> <td>-</td> <td>27</td> <td>31</td> </tr> <tr> <th>E</th> <td>20</td> <td>17</td> <td>9</td> <td>27</td> <td>-</td> <td>17</td> </tr> <tr> <th>F</th> <td>37</td> <td>32</td> <td>26</td> <td>31</td> <td>17</td> <td>-</td> </tr> </tbody> </table>		A	B	C	D	E	F	A	-	19	11	23	20	37	B	19	-	8	42	17	32	C	11	8	-	34	9	26	D	23	42	34	-	27	31	E	20	17	9	27	-	17	F	37	32	26	31	17	-	<p>B3, 2, 1, 0 (3)</p>
	A	B	C	D	E	F																																													
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<p>(b)</p>	<p>A C B E F D A 11 8 17 17 31 23 = 107</p>	<p>M1 A1 A1 (3)</p>																																																	
<p>(c)</p>	<p>Delete A</p>  <p>RMST weight = 61 Lower bound = 61 + 11 + 19 = 91 km</p>	<p>M1 A1 M1 A1 (4) 10</p>																																																	

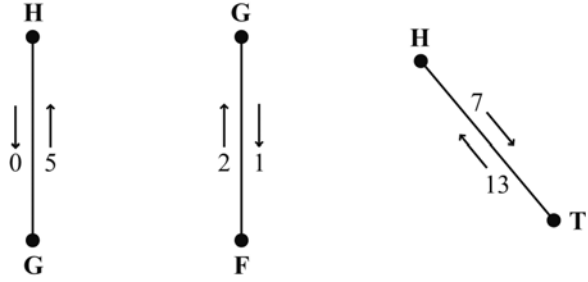
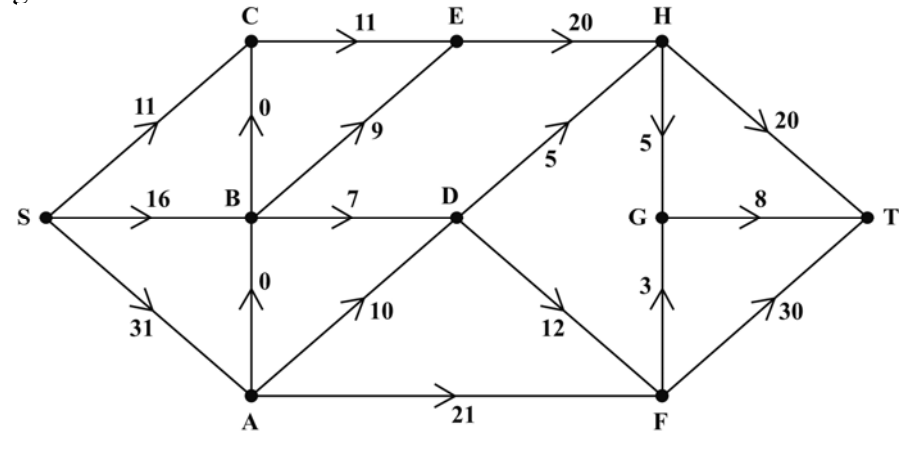
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<p>(a)1B1 2B1 3B1 (b)M1 1A1 2A1 (c)1M1 1A1 2M1 2A1</p>	<p style="text-align: center;"><u>Notes:</u></p> <p>One double entry correct Two double entries correct Three double entries correct NN route, each letter appearing once, condone lack of return vertex CAO CAO Finding my RMST – accept 61 for both marks Either $8 + 9 + 17 + 27$ or 61 seen Adding on two least arcs, accept 11 and 19 or AC and AB 91 CAO</p>																																					
<p>2. (a)</p>	<p>Adds a column of four zeros and 10.</p> <table border="1" data-bbox="327 976 940 1245"> <thead> <tr> <th>Shadow costs</th> <th></th> <th>31</th> <th>42</th> <th>47</th> <th>9</th> </tr> <tr> <td></td> <td></td> <td>A</td> <td>B</td> <td>C</td> <td>D</td> </tr> </thead> <tbody> <tr> <td>0</td> <td>1</td> <td>x</td> <td>-13</td> <td>-15</td> <td>-9</td> </tr> <tr> <td>-9</td> <td>2</td> <td>x</td> <td>x</td> <td>-11</td> <td>0</td> </tr> <tr> <td>-15</td> <td>3</td> <td>9</td> <td>x</td> <td>x</td> <td>6</td> </tr> <tr> <td>-9</td> <td>4</td> <td>1</td> <td>-7</td> <td>x</td> <td>x</td> </tr> </tbody> </table>	Shadow costs		31	42	47	9			A	B	C	D	0	1	x	-13	-15	-9	-9	2	x	x	-11	0	-15	3	9	x	x	6	-9	4	1	-7	x	x	<p>B1 (1) M1 A1 M1 A1 (4)</p>
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(a)	1B1: cao																																																																																						
(b)	1M1: Finding all 8 shadow costs 1A1: cao 2M1: Finding missing four improvement indices – no extra zeros 2A1: cao																																																																																						
(c)	1M1: A valid route, their most negative II chosen, only one empty square used, θ 's balance. 1A1ft: consistent; their entering and exiting cells stated clearly 2DM1: An improved solution 7 entries only, (so must now be using one of my negative indices as the entering cell). Must fit from their valid route. 2A1: cao																																																																																						
3.																																																																																							
(a)	$P - 7x + z + 4s = 320$	M1 A1 (2)																																																																																					
(b)	<table border="1" data-bbox="328 1189 1046 1424"> <thead> <tr> <th>b.v.</th> <th>x</th> <th>y</th> <th>z</th> <th>r</th> <th>s</th> <th>t</th> <th>Value</th> </tr> </thead> <tbody> <tr> <td>r</td> <td>$-\frac{1}{2}$</td> <td>0</td> <td>2</td> <td>1</td> <td>$-\frac{1}{2}$</td> <td>0</td> <td>10</td> </tr> <tr> <td>y</td> <td>$\frac{1}{2}$</td> <td>1</td> <td>$\frac{3}{4}$</td> <td>0</td> <td>$\frac{1}{4}$</td> <td>0</td> <td>5</td> </tr> <tr> <td>t</td> <td>$\frac{1}{2}$</td> <td>0</td> <td>1</td> <td>0</td> <td>$-\frac{1}{4}$</td> <td>1</td> <td>4</td> </tr> <tr> <td>P</td> <td>-7</td> <td>0</td> <td>1</td> <td>0</td> <td>4</td> <td>0</td> <td>320</td> </tr> </tbody> </table> <table border="1" data-bbox="328 1464 1211 1718"> <thead> <tr> <th>b.v.</th> <th>x</th> <th>y</th> <th>z</th> <th>r</th> <th>s</th> <th>t</th> <th>Value</th> <th>Row ops.</th> </tr> </thead> <tbody> <tr> <td>r</td> <td>0</td> <td>0</td> <td>3</td> <td>1</td> <td>$-\frac{3}{4}$</td> <td>1</td> <td>14</td> <td>$R_1 + \frac{1}{2}R_3$</td> </tr> <tr> <td>y</td> <td>0</td> <td>1</td> <td>$-\frac{1}{4}$</td> <td>0</td> <td>$\frac{1}{2}$</td> <td>-1</td> <td>1</td> <td>$R_2 - \frac{1}{2}R_3$</td> </tr> <tr> <td>x</td> <td>1</td> <td>0</td> <td>2</td> <td>0</td> <td>$-\frac{1}{2}$</td> <td>2</td> <td>8</td> <td>$R_3 \div \frac{1}{2}$</td> </tr> <tr> <td>P</td> <td>0</td> <td>0</td> <td>15</td> <td>0</td> <td>$\frac{1}{2}$</td> <td>14</td> <td>376</td> <td>$R_4 + 7R_3$</td> </tr> </tbody> </table>	b.v.	x	y	z	r	s	t	Value	r	$-\frac{1}{2}$	0	2	1	$-\frac{1}{2}$	0	10	y	$\frac{1}{2}$	1	$\frac{3}{4}$	0	$\frac{1}{4}$	0	5	t	$\frac{1}{2}$	0	1	0	$-\frac{1}{4}$	1	4	P	-7	0	1	0	4	0	320	b.v.	x	y	z	r	s	t	Value	Row ops.	r	0	0	3	1	$-\frac{3}{4}$	1	14	$R_1 + \frac{1}{2}R_3$	y	0	1	$-\frac{1}{4}$	0	$\frac{1}{2}$	-1	1	$R_2 - \frac{1}{2}R_3$	x	1	0	2	0	$-\frac{1}{2}$	2	8	$R_3 \div \frac{1}{2}$	P	0	0	15	0	$\frac{1}{2}$	14	376	$R_4 + 7R_3$	2M1 2A1ft 1M1 2A1 3A1 (5)
b.v.	x	y	z	r	s	t	Value																																																																																
r	$-\frac{1}{2}$	0	2	1	$-\frac{1}{2}$	0	10																																																																																
y	$\frac{1}{2}$	1	$\frac{3}{4}$	0	$\frac{1}{4}$	0	5																																																																																
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P	0	0	15	0	$\frac{1}{2}$	14	376	$R_4 + 7R_3$																																																																															
(c)	$P = 376 \quad x = 8 \quad y = 1 \quad z = 0 \quad r = 14 \quad s = 0 \quad t = 0$	M1 A1ft A1 (3) 10																																																																																					

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	<p><u>Notes:</u></p>	
(a)	1M1: One equal sign, P and 320 present 1A1: cao	
(b)	1M1: correct pivot located, attempt to divide row. If choosing negative pivot M0M0 in (b) 1A1: pivot row correct including change of b.v. 2M1: (ft) Correct row operations used at least once or stated correctly. 2A1ft: Looking at non zero-and-one columns, one column ft correct 3A1: cao.	
(c)	1M1: At least 4 values stated. Reading off bottom row, or negative values get M0. 1A1ft: Their four basic variables correct ft from their table. 2A1: cao	

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<p>4.</p> <p>(a)</p>	<table border="1" data-bbox="331 340 1018 495"> <thead> <tr> <th></th> <th>S plays 1</th> <th>S plays 2</th> <th>S plays 3</th> </tr> </thead> <tbody> <tr> <td>L plays 1</td> <td>-4</td> <td>-1</td> <td>1</td> </tr> <tr> <td>L plays 2</td> <td>3</td> <td>-1</td> <td>-2</td> </tr> <tr> <td>L plays 3</td> <td>-3</td> <td>0</td> <td>2</td> </tr> </tbody> </table> <p>Row 3 dominates row 1 so row 1 may be deleted.</p> <table border="1" data-bbox="331 607 995 719"> <thead> <tr> <th></th> <th>S plays 1</th> <th>S plays 2</th> <th>S plays 3</th> </tr> </thead> <tbody> <tr> <td>L plays 2</td> <td>3</td> <td>-1</td> <td>-2</td> </tr> <tr> <td>L plays 3</td> <td>-3</td> <td>0</td> <td>2</td> </tr> </tbody> </table> <p>Let Laura play 2 with probability p and 3 with probability $(1-p)$</p> <p>If Sam plays 1: Laura's gain is $3p - 3(1-p) = -3 + 6p$</p> <p>If Sam plays 2: Laura's gain is $-p + 0(1-p) = -p$</p> <p>If Sam plays 3: Laura's gain is $-2p + 2(1-p) = 2 - 4p$</p>		S plays 1	S plays 2	S plays 3	L plays 1	-4	-1	1	L plays 2	3	-1	-2	L plays 3	-3	0	2		S plays 1	S plays 2	S plays 3	L plays 2	3	-1	-2	L plays 3	-3	0	2	<p>M1</p> <p>M1</p> <p>A1</p> <p>(3)</p>
	S plays 1	S plays 2	S plays 3																											
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<p>(b)</p>		<p>B2, 1ft, 0</p> <p>(2)</p>																												
<p>(c)</p>	$-3 + 6p = -p$ $7p = 3$ $p = \frac{3}{7}$ <p>Laura should play row 1: never,</p> <p>row 2: $\frac{3}{7}$ of the time and</p> <p>row 3: $\frac{4}{7}$ of the time</p> <p>and the value of the game is $-\frac{3}{7}$ to her.</p>	<p>M1</p> <p>A1</p> <p>A1ft</p> <p>A1</p> <p>(4)</p> <p>9</p>																												

Question Number	Scheme	Marks
	<p style="text-align: center;"><u>Notes:</u></p> <p>(a) 1M1: Matrix reduced correctly. Could be implicit from equations. 2M1: Setting up three probability equations, implicit definition of p. 1A1: CAO</p> <p>(b) 1B1ft: At least two lines correct, accept $p > 1$ or $p < 0$ here. Must both be function of p. 2B1: 3 lines cao, $0 \leq p \leq 1$, scale clear (or 1 line = 1), condone lack of labels. Rulers used.</p> <p>(c) 3M1: Finding their correct optimal point, must have three lines, and setting up an equation to find $0 \leq p \leq 1$. 1A1: CAO 2A1ft: All three options listed must ft from their p, check page 1, no negatives. 3A1: CAO</p>	

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<p>5.</p> <p>(a)</p>	<p>$a = 1 \quad b = 5 \quad c = 13 \quad \text{Flow} = 49$</p>	<p>B1, B1 B1, B1 (4)</p>
<p>(b)</p>		<p>M1 A1 (2)</p>
<p>(c)</p>	<p>e.g. SBEHT - 7 together with either SBEHDAFGT - 2 or SBCEHDAFGT - 2</p>	<p>M1 A1 A2,1,0 (4)</p>
<p>(d)</p>	<p>58</p>	<p>B1 (1)</p>
<p>(e)</p>	<p>e.g.</p> 	<p>M1 A1 (2)</p>
<p>(f)</p>	<p>Max flow = min cut Cut through HT, HG, GF, FT Value 58</p>	<p>M1 A1 (2) 15</p>

Question Number	Scheme	Marks
	<u>Notes:</u>	
(a)	1B1: $a = 1$ cao 2B1: $b = 5$ cao 3B1: $c = 13$ cao 4B1: 49 cao	
(b)	1M1: Two numbers on each arc 1A1: cao	
(c)	1M1: One valid flow augmenting route found and value stated. 1A1: Flow increased by at least 2 2A1: A second correct flow 3A1: Flow increased by 9 and no more	
(d)	1B1: cao	
(e)	1M1: Consistent flow pattern > 51 1A1: cao	
(f)	1M1: Must have attempted (e), S to T, and made an attempt at a cut. 1A1: cut correct – may be drawn. Refer to max flow-min cut theorem three words out of four.	

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6. (a)	<table border="1" data-bbox="331 309 995 495"> <thead> <tr> <th></th> <th>Task A</th> <th>Task B</th> <th>Task C</th> </tr> </thead> <tbody> <tr> <td>Worker P</td> <td>27</td> <td>31</td> <td>25</td> </tr> <tr> <td>Worker Q</td> <td>26</td> <td>30</td> <td>34</td> </tr> <tr> <td>Worker R</td> <td>35</td> <td>29</td> <td>32</td> </tr> </tbody> </table> <p data-bbox="308 533 762 622">Let $x_{ij} = \begin{cases} 1 & \text{if worker does the task} \\ 0 & \text{otherwise} \end{cases}$</p> <p data-bbox="308 633 1171 723">Where x_{ij} indicates worker i being assigned to task j, $i \in \{P, Q, R\}$, $j \in \{A, B, C\}$</p> <p data-bbox="308 775 1214 853">Minimise $27x_{PA} + 31x_{PB} + 25x_{PC} + 26x_{QA} + 30x_{QB} + 34x_{QC} + 35x_{RA} + 29x_{RB} + 32x_{RC}$</p> <p data-bbox="308 882 584 1234">Subject to: $x_{PA} + x_{PB} + x_{PC} = 1$ $x_{QA} + x_{QB} + x_{QC} = 1$ $x_{RA} + x_{RB} + x_{RC} = 1$ $x_{PA} + x_{QA} + x_{RA} = 1$ $x_{PB} + x_{QB} + x_{RB} = 1$ $x_{PC} + x_{QC} + x_{RC} = 1$</p>		Task A	Task B	Task C	Worker P	27	31	25	Worker Q	26	30	34	Worker R	35	29	32	 B1 B1 B1 B1 M1 A1 A1 (7)
	Task A	Task B	Task C															
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(b)	<p data-bbox="308 1330 1206 1364">Since we need to maximise first subtract all entries from some $n \geq 41$</p> <table border="1" data-bbox="331 1435 1038 1592"> <thead> <tr> <th></th> <th>Task A</th> <th>Task B</th> <th>Task C</th> </tr> </thead> <tbody> <tr> <td>Worker P</td> <td>8</td> <td>4</td> <td>10</td> </tr> <tr> <td>Worker Q</td> <td>9</td> <td>5</td> <td>1</td> </tr> <tr> <td>Worker R</td> <td>0</td> <td>6</td> <td>3</td> </tr> </tbody> </table>		Task A	Task B	Task C	Worker P	8	4	10	Worker Q	9	5	1	Worker R	0	6	3	M1 A1 (2) 9
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Worker Q	9	5	1															
Worker R	0	6	3															

Question Number	Scheme	Marks																																																																																	
	<p style="text-align: center;">Notes:</p> <p>(a) 1B1: defining variables 2B1: defining variables 3B1: minimise 4B1: cao 1M1: At least 3 equations, coefficients of 1. Accept inequalities here should be precisely 9 variables. 1A1: cao 3 equations correct accept slack variables if defined 2A1: cao 6 equations correct accept slack variables if defined</p> <p>(b) 1M1: subtracting from some $n \geq 41$ condone up to two errors 1A1: correct</p>																																																																																		
<p>7.</p> <p>(a)</p>	<table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th>Stage</th> <th>State</th> <th>Action</th> <th>Dest.</th> <th>Value</th> </tr> </thead> <tbody> <tr> <td rowspan="2">0</td> <td>H</td> <td>H- London</td> <td>London</td> <td>$36 - 5 = 31^*$</td> </tr> <tr> <td>I</td> <td>I - London</td> <td>London</td> <td>$38 - 4 = 34^*$</td> </tr> <tr> <td rowspan="4">1</td> <td rowspan="2">F</td> <td>FH</td> <td>H</td> <td>$29 - 6 + 31 = 54$</td> </tr> <tr> <td>FI</td> <td>I</td> <td>$29 - 7 + 34 = 56^*$</td> </tr> <tr> <td rowspan="2">G</td> <td>GH</td> <td>H</td> <td>$27 - 5 + 31 = 53$</td> </tr> <tr> <td>GI</td> <td>I</td> <td>$27 - 6 + 34 = 55^*$</td> </tr> <tr> <td rowspan="6">2</td> <td rowspan="2">C</td> <td>CF</td> <td>F</td> <td>$42 - 6 + 56 = 92^*$</td> </tr> <tr> <td>CG</td> <td>G</td> <td>$42 - 5 + 55 = 92^*$</td> </tr> <tr> <td rowspan="2">D</td> <td>DF</td> <td>F</td> <td>$41 - 6 + 56 = 91$</td> </tr> <tr> <td>DG</td> <td>G</td> <td>$41 - 3 + 55 = 93^*$</td> </tr> <tr> <td rowspan="2">E</td> <td>EF</td> <td>F</td> <td>$39 - 4 + 56 = 91^*$</td> </tr> <tr> <td>EG</td> <td>G</td> <td>$39 - 4 + 55 = 90$</td> </tr> <tr> <td rowspan="6">3</td> <td rowspan="3">A</td> <td>AC</td> <td>C</td> <td>$22 - 5 + 92 = 109$</td> </tr> <tr> <td>AD</td> <td>D</td> <td>$22 - 4 + 93 = 111^*$</td> </tr> <tr> <td>AE</td> <td>E</td> <td>$22 - 2 + 91 = 111^*$</td> </tr> <tr> <td rowspan="3">B</td> <td>BC</td> <td>C</td> <td>$17 - 4 + 92 = 105$</td> </tr> <tr> <td>BD</td> <td>D</td> <td>$17 - 4 + 93 = 106^*$</td> </tr> <tr> <td>BE</td> <td>E</td> <td>$17 - 3 + 91 = 105$</td> </tr> <tr> <td rowspan="2">4</td> <td>London</td> <td>London - A</td> <td>A</td> <td>$-5 + 111 = 106^*$</td> </tr> <tr> <td></td> <td>London - B</td> <td>B</td> <td>$-3 + 106 = 103$</td> </tr> </tbody> </table> <p>Optimal expected income is £10 600</p>	Stage	State	Action	Dest.	Value	0	H	H- London	London	$36 - 5 = 31^*$	I	I - London	London	$38 - 4 = 34^*$	1	F	FH	H	$29 - 6 + 31 = 54$	FI	I	$29 - 7 + 34 = 56^*$	G	GH	H	$27 - 5 + 31 = 53$	GI	I	$27 - 6 + 34 = 55^*$	2	C	CF	F	$42 - 6 + 56 = 92^*$	CG	G	$42 - 5 + 55 = 92^*$	D	DF	F	$41 - 6 + 56 = 91$	DG	G	$41 - 3 + 55 = 93^*$	E	EF	F	$39 - 4 + 56 = 91^*$	EG	G	$39 - 4 + 55 = 90$	3	A	AC	C	$22 - 5 + 92 = 109$	AD	D	$22 - 4 + 93 = 111^*$	AE	E	$22 - 2 + 91 = 111^*$	B	BC	C	$17 - 4 + 92 = 105$	BD	D	$17 - 4 + 93 = 106^*$	BE	E	$17 - 3 + 91 = 105$	4	London	London - A	A	$-5 + 111 = 106^*$		London - B	B	$-3 + 106 = 103$	<p>1M1 1A1 (2)</p> <p>2M1 2A1</p> <p>3A1 (3)</p> <p>3M1 4A1ft</p> <p>5A1ft (3)</p> <p>4M1 6A1ft</p> <p>7A1ft (3)</p>
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<p>(b)</p>	<p>Optimal schedules are: London - A - D - G - I - London (or v.v.) London - A - E - F - I - London (or v.v.)</p>	<p>B1ft B1 (2) 13</p>																																																																																	

Question Number	Scheme	Marks
	<p style="text-align: center;"><u>Notes:</u></p> <p>Throughout section (a):</p> <ul style="list-style-type: none"> • Condone lack of destination column and/or reversed stage numbers throughout. • Only penalise incorrect result in Value – ie ignore working values. • Penalise absence of state or action column with first two A marks earned only • Penalise empty/errors in stage column with first A mark earned only. <p>(a)</p> <p>1M1: First stage completed. 1A1: CAO Penalise * errors only once in the question on the first occurrence</p> <p>2M1: Second stage completed. Penalise reversed states here and at end. Bod if something in each cell. 2A1: Any 2 states correct. (Penalise * errors only once in the question). 3A1: All 3 states correct. (Penalise * errors only once in the question).</p> <p>3M1: 3rd stage completed. Bod if something in each cell. 4A1ft: A or B state correct. (Penalise * errors only once in the question). 5A1ft: A and B states correct. (Penalise * errors only once in the question).</p> <p>4M1: 4th stage completed. Bod if something in each cell. 6A1ft: Final, state correct. (Penalise * errors only once in the question). 7A1ft: CAO</p> <p>(b)</p> <p>1B1ft: 1 route correct, consistent with their working penalise reversed states again here. Condone absence of London 2B1: both routes cao. London to London.</p>	

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