

Mathematics

Advanced GCE **4737**

Decision Mathematics 2

Mark Scheme for June 2010

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Mark schemes should be read in conjunction with the published question papers and the Report on the Examination.

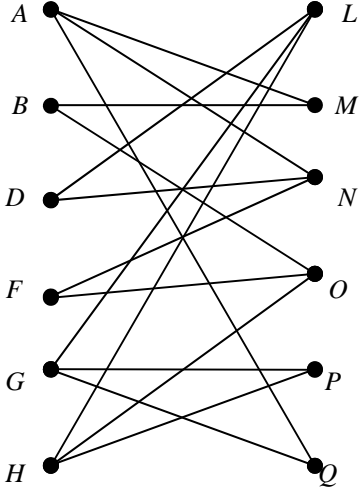
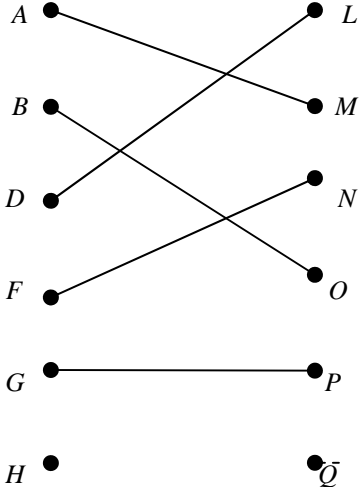
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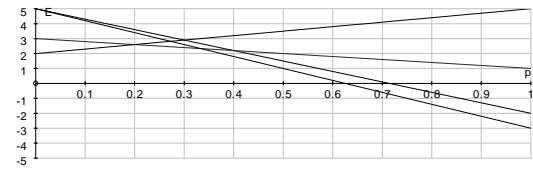
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<p>1</p>	<p>(i)</p>		<p>B1</p>	<p>A correct bipartite graph</p>	<p>[1]</p>
	<p>(ii)</p>		<p>B1</p>	<p>A second bipartite graph showing the incomplete matching correctly</p> <p>No augmentations made, even if in pencil. Ignore the addition of an <i>X</i> vertex though.</p>	<p>[1]</p>
	<p>(iii)</p>	<p><i>H - P - G - Q</i></p> <p>Axe handle = Prof Mulberry <i>A = M</i> Broomstick = Miss Olive <i>B = O</i> Drainpipe = Mrs Lemon <i>D = L</i> Fence post = Mr Nutmeg <i>F = N</i> Golf club = Rev Quince <i>G = Q</i> Hammer = Capt Peach <i>H = P</i></p>	<p>B1</p> <p>B1</p>	<p>This path in any reasonable form or in reverse. Accept <i>X-H-P-G-Q</i> Not any longer path from <i>H</i> to <i>Q</i></p> <p>This complete matching written down (use initials of surnames if ambiguous, eg Rev Pineapple is interpreted as <i>P = Capt Peach</i>)</p>	<p>[2]</p>
	<p>(iv)</p>	<p>Axe handle = Rev Quince <i>A = Q</i> Broomstick = Prof Mulberry <i>B = M</i> Drainpipe = Mr Nutmeg <i>D = N</i> Fence post = Miss Olive <i>F = O</i> Golf club = Capt Peach <i>G = P</i> Hammer = Mrs Lemon <i>H = L</i></p>	<p>M1</p> <p>A1</p>	<p>A different complete matching in any form</p> <p>A valid complete matching in which none of the suspects uses the same weapon as in their solution to (iii)</p>	<p>[2]</p>
<p>Total =</p>					<p>6</p>

2	(i)	<table border="1"> <thead> <tr> <th></th> <th>1 pm</th> <th>2 pm</th> <th>3 pm</th> <th>4 pm</th> <th>5 pm</th> </tr> </thead> <tbody> <tr> <td><i>R</i></td> <td>7</td> <td>6</td> <td>8</td> <td>3</td> <td>9</td> </tr> <tr> <td><i>S</i></td> <td>5</td> <td>0</td> <td>4</td> <td>4</td> <td>4</td> </tr> <tr> <td><i>T</i></td> <td>6</td> <td>3</td> <td>7</td> <td>5</td> <td>7</td> </tr> <tr> <td><i>W</i></td> <td>4</td> <td>2</td> <td>6</td> <td>2</td> <td>7</td> </tr> <tr> <td><i>Y</i></td> <td>2</td> <td>2</td> <td>3</td> <td>6</td> <td>7</td> </tr> </tbody> </table>		1 pm	2 pm	3 pm	4 pm	5 pm	<i>R</i>	7	6	8	3	9	<i>S</i>	5	0	4	4	4	<i>T</i>	6	3	7	5	7	<i>W</i>	4	2	6	2	7	<i>Y</i>	2	2	3	6	7	M1	Modify table by subtracting each entry from a constant value	[2]
			1 pm	2 pm	3 pm	4 pm	5 pm																																		
<i>R</i>	7	6	8	3	9																																				
<i>S</i>	5	0	4	4	4																																				
<i>T</i>	6	3	7	5	7																																				
<i>W</i>	4	2	6	2	7																																				
<i>Y</i>	2	2	3	6	7																																				
A1	Correct table (ie this \pm a constant throughout, with no negative values)																																								
	Reduce rows	<table border="1"> <tbody> <tr><td>4</td><td>3</td><td>5</td><td>0</td><td>6</td></tr> <tr><td>5</td><td>0</td><td>4</td><td>4</td><td>4</td></tr> <tr><td>3</td><td>0</td><td>4</td><td>2</td><td>4</td></tr> <tr><td>2</td><td>0</td><td>4</td><td>0</td><td>5</td></tr> <tr><td>0</td><td>0</td><td>1</td><td>4</td><td>5</td></tr> </tbody> </table>	4	3	5	0	6	5	0	4	4	4	3	0	4	2	4	2	0	4	0	5	0	0	1	4	5	M1	Substantially correct attempt to reduce rows (at most 2 independent errors)	[3]											
4	3	5	0	6																																					
5	0	4	4	4																																					
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3	0	3	2	0																																					
2	0	3	0	1																																					
0	0	0	4	1																																					
	Cross out 0's using minimum no. of lines	<table border="1"> <tbody> <tr><td>4</td><td>3</td><td>4</td><td>0</td><td>2</td></tr> <tr><td>5</td><td>0</td><td>3</td><td>4</td><td>0</td></tr> <tr><td>3</td><td>0</td><td>3</td><td>2</td><td>0</td></tr> <tr><td>2</td><td>0</td><td>3</td><td>0</td><td>1</td></tr> <tr><td>0</td><td>0</td><td>0</td><td>4</td><td>1</td></tr> </tbody> </table>	4	3	4	0	2	5	0	3	4	0	3	0	3	2	0	2	0	3	0	1	0	0	0	4	1	A1	Their reduced cost matrix												
4	3	4	0	2																																					
5	0	3	4	0																																					
3	0	3	2	0																																					
2	0	3	0	1																																					
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	Augment	<table border="1"> <tbody> <tr><td>2</td><td>3</td><td>2</td><td>0</td><td>2</td></tr> <tr><td>3</td><td>0</td><td>1</td><td>4</td><td>0</td></tr> <tr><td>1</td><td>0</td><td>1</td><td>2</td><td>0</td></tr> <tr><td>0</td><td>0</td><td>1</td><td>0</td><td>1</td></tr> <tr><td>0</td><td>2</td><td>0</td><td>6</td><td>3</td></tr> </tbody> </table>	2	3	2	0	2	3	0	1	4	0	1	0	1	2	0	0	0	1	0	1	0	2	0	6	3	M1	Substantially correct attempt at augmenting (at most 2 errors)	[2]											
2	3	2	0	2																																					
3	0	1	4	0																																					
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0	0	1	0	1																																					
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	1 pm	2 pm	3 pm	4 pm	5 pm																																				
<i>R</i>	2	3	2	0	2																																				
<i>S</i>	3	0	1	4	0																																				
<i>T</i>	1	0	1	2	0																																				
<i>W</i>	0	0	1	0	1																																				
<i>Y</i>	0	2	0	6	3																																				
		<p>Mrs Rowan = 4 pm or = 4 pm Dr Silverbirch = 2 pm or = 5 pm Mr Thorn = 5 pm or = 2 pm Ms Willow = 1 pm or = 1 pm Sgt Yew = 3 pm or = 3 pm</p>	B1	First matching, cao	[2]																																				
			B1	Second matching, cao																																					
	(ii)	Mr Thorn	B1	Follow through their matchings (but not to S)	[1]																																				
Total =					10																																				

3	(i)	<table border="1"> <thead> <tr> <th>Stage</th> <th>State</th> <th>Action</th> <th>Working</th> <th>Suboptimal minima</th> </tr> </thead> <tbody> <tr> <td rowspan="3">3</td> <td>0</td> <td>0</td> <td>5</td> <td>5</td> </tr> <tr> <td>1</td> <td>0</td> <td>4</td> <td>4</td> </tr> <tr> <td>2</td> <td>0</td> <td>6</td> <td>6</td> </tr> <tr> <td rowspan="6">2</td> <td rowspan="2">0</td> <td>0</td> <td>5 + 5 = 10</td> <td>10</td> </tr> <tr> <td>1</td> <td>6 + 4 = 10</td> <td>10</td> </tr> <tr> <td rowspan="2">1</td> <td>0</td> <td>3 + 5 = 8</td> <td rowspan="2">8</td> </tr> <tr> <td>1</td> <td>5 + 4 = 9</td> </tr> <tr> <td rowspan="2">2</td> <td>1</td> <td>3 + 4 = 7</td> <td rowspan="2">7</td> </tr> <tr> <td>2</td> <td>2 + 6 = 8</td> </tr> <tr> <td rowspan="4">1</td> <td rowspan="2">0</td> <td>0</td> <td>2 + 10 = 12</td> <td rowspan="2">11</td> </tr> <tr> <td>1</td> <td>3 + 8 = 11</td> </tr> <tr> <td rowspan="2">1</td> <td>1</td> <td>2 + 8 = 10</td> <td>10</td> </tr> <tr> <td>2</td> <td>3 + 7 = 10</td> <td>10</td> </tr> <tr> <td rowspan="3">0</td> <td rowspan="3">0</td> <td>0</td> <td>6 + 11 = 17</td> <td rowspan="3">17</td> </tr> <tr> <td>1</td> <td>8 + 10 = 18</td> </tr> <tr> <td>2</td> <td>3 + 15 = 18</td> </tr> </tbody> </table>	Stage	State	Action	Working	Suboptimal minima	3	0	0	5	5	1	0	4	4	2	0	6	6	2	0	0	5 + 5 = 10	10	1	6 + 4 = 10	10	1	0	3 + 5 = 8	8	1	5 + 4 = 9	2	1	3 + 4 = 7	7	2	2 + 6 = 8	1	0	0	2 + 10 = 12	11	1	3 + 8 = 11	1	1	2 + 8 = 10	10	2	3 + 7 = 10	10	0	0	0	6 + 11 = 17	17	1	8 + 10 = 18	2	3 + 15 = 18	<p>B1 Structure of table correct (stage, state, action and 'working' columns)</p> <p>M1 Stage and state values correct</p> <p>A1 Action values correct</p> <p>[3]</p> <p>M1 Working column substantially correct for stage 2 (calcs or totals) (at most 1 error)</p> <p>A1 Suboptimal minima (10, 8, 7) correct for stage 2 (cao)</p> <p>[2]</p> <p>M1 Working column substantially correct for stage 1 (at most 1 error)</p> <p>A1 Suboptimal minima (11, 10, 15) correct for stage 1 (cao)</p> <p>[2]</p> <p>B1 Correct route from (0; 0) to (4; 0)</p> <p>B1 17 cao (written down, not just implied from table)</p> <p>[2]</p>	
		Stage	State	Action	Working	Suboptimal minima																																																											
3	0	0	5	5																																																													
	1	0	4	4																																																													
	2	0	6	6																																																													
2	0	0	5 + 5 = 10	10																																																													
		1	6 + 4 = 10	10																																																													
	1	0	3 + 5 = 8	8																																																													
		1	5 + 4 = 9																																																														
	2	1	3 + 4 = 7	7																																																													
		2	2 + 6 = 8																																																														
1	0	0	2 + 10 = 12	11																																																													
		1	3 + 8 = 11																																																														
	1	1	2 + 8 = 10	10																																																													
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0	0	0	6 + 11 = 17	17																																																													
		1	8 + 10 = 18																																																														
		2	3 + 15 = 18																																																														
	(ii)	<p>Start at the bottom of the table at (0; 0)</p> <p>Optimum for stage 0 comes from action 0, so (0; 0) connects to (1; 0)</p> <p>Optimum for (1; 0) comes from action 1, so (1; 0) connects to (2; 1)</p> <p>Optimum for (2; 1) comes from action 0 so (2; 1) connects to (3; 0) and hence to (4; 0)</p>	<p>M1 Start at (0; 0), action 0 or value 11 (theirs), hence (1; 0)</p> <p>A1 (1; 0), action 1 (theirs), hence (2; 1)</p> <p>Clearly relating <u>action</u> to state for stage above</p> <p>[2]</p>																																																														
Total = 11																																																																	

4	(i)	In each game, whatever combination of strategies is chosen, the total number of points won is zero	B1	Points won by Euan equals points lost by Wai Mai, and vice versa, in every case	[1]																																					
	(ii)	-2	B1	Loses 2	[1]																																					
	(iii)	Z is dominated by Y In <u>each</u> row she loses more by choosing Z than Y -3 < 5, -4 < 3, -2 < 5 and 1 < 2 (or equivalent)	M1 A1	Idea of dominance by Y Four valid comparisons <u>and</u> a convincing explanation (or equivalent in words)	[2]																																					
	(iv)	<table style="margin-left: auto; margin-right: auto;"> <thead> <tr> <th colspan="2"></th> <th colspan="2">Wai Mai</th> <th></th> </tr> <tr> <th colspan="2"></th> <th>X</th> <th>Y</th> <th>row min</th> </tr> </thead> <tbody> <tr> <td rowspan="4" style="vertical-align: middle;">Euan</td> <td>A</td> <td>2</td> <td>-5</td> <td>-5</td> </tr> <tr> <td>B</td> <td>-1</td> <td>-3</td> <td>-3</td> </tr> <tr> <td>C</td> <td>3</td> <td>-5</td> <td>-5</td> </tr> <tr> <td>D</td> <td>3</td> <td>-2</td> <td>-2</td> </tr> <tr> <td colspan="2" style="text-align: right;">col max</td> <td>3</td> <td>-2</td> <td>*</td> </tr> <tr> <td colspan="2"></td> <td></td> <td>*</td> <td></td> </tr> </tbody> </table> <p>Play-safe for Euan is D Play-safe for Wai Mai is Y</p> <p>Game is stable, since row maximin = col minimax, -2 = -2</p>			Wai Mai					X	Y	row min	Euan	A	2	-5	-5	B	-1	-3	-3	C	3	-5	-5	D	3	-2	-2	col max		3	-2	*				*		M1 A1 A1 B1	Determining row minima and column maxima, or equivalent (may be implied from both D and Y stated) D, stated (not just identified in table) Y, stated (not just identified in table) Stable, with a valid reason attempted (numerical or in words) (www)	[4]
		Wai Mai																																								
		X	Y	row min																																						
Euan	A	2	-5	-5																																						
	B	-1	-3	-3																																						
	C	3	-5	-5																																						
	D	3	-2	-2																																						
col max		3	-2	*																																						
			*																																							
	(v)	$A: -2p + 5(1-p) = 5 - 7p$ $B: p + 3(1-p) = 3 - 2p$ $C: -3p + 5(1-p) = 5 - 8p$ $D: 5p + 2(1-p) = 2 + 3p$ (note: leaving DX as 3 gives D: $2 - 5p = M1A0A0$)	M1 A1 A1	Any one correct (or negative of correct), simplified or not All four correct (or negative of correct) and simplified All four correct and simplified	[3]																																					
	(vi)	 <p>$2 + 3p = 3 - 2p$ $\Rightarrow p = 0.2$</p>	M1 A1 M1 A1	Graph paper used with sensible scales Their equations plotted correctly Solving correct pair, or from graph 0.2, cao, from correct equations used (algebraically or from graph) (www)	[2] [2]																																					
Total =					15																																					

ANSWERED ON INSERT

5	(i)	21+36+7+18 = 82	M1 A1	Evidence of using the correct cut (eg $21 (\pm 23) + 36 + 7 + 18$ seen) 82	[2]
	(ii)	At most 17 can leave <i>C</i> so there cannot be as much as 20 or 18 entering it At most 17 can enter <i>E</i> so there cannot be $7 + 18 = 25$ leaving it Maximum that can flow in arc <i>HT</i> is 33 Flow along arc <i>HG</i> = 0	B1 B1 B1 B1	17 < both 20 and 18 (NOT $17 < 38$) $17 < 7 + 18$ 33 0	[2] [2] [2]
	(iii)	A diagram showing a flow of 58 in which amount in equals amount out at each vertex, apart from <i>S</i> and <i>T</i> Arcs <i>CE</i> , <i>FH</i> and <i>GT</i> are saturated and other arc capacities are not exceeded Cut $X = \{S, A, B, C, D, F, G\}$, $Y = \{E, H, T\}$ Or cut through <i>GT</i> , <i>GH</i> , <i>FH</i> , <i>EF</i> and <i>CE</i>	M1 A1 B1	Assume that “blanks” mean 0 or full to capacity, provided consistent This cut presented in any form (accept it drawn on diagram)	[3]
	(iv)	Substantially correct attempt in which excess capacities and potential backflows marked correctly on arcs <i>CE</i> , <i>FH</i> and <i>GT</i> Their excess capacities and potential backflows marked correctly on arcs out of <i>S</i> and arcs into <i>T</i> and on <i>HG</i>	M1 A1	Assume that blanks mean 0 Accept <u>all</u> directions swapped Check directions on <u>HG</u> carefully If no flow in (iii), or ambiguous, then any valid flow > 0 labelled correctly gets M1, but must also be a flow of 58 to get A1	[2]
	(v)	Feasible route(s) written that send an additional 2 through system (or more on follow through) All route(s) valid with an additional 2 along <i>GH</i>	M1 A1	Routes must be written out properly eg route <i>S B F G H T</i> by 2	[2]
	(vi)	Their flow from part (iii) augmented by their routes in part (v) No more can flow across the cut $X = \{S, C\}$, $Y = \{A, B, D, E, F, G, H, T\}$	M1 A1	Follow through if possible Any reasonable explanation	[2]
				Total =	15

PARTS (i), (ii) AND (iii) ANSWERED ON INSERT

6	(i)	<table border="1"> <thead> <tr> <th>Activity</th> <th>Duration</th> <th>Predecessors</th> </tr> </thead> <tbody> <tr><td>A</td><td>6</td><td>-</td></tr> <tr><td>B</td><td>5</td><td>-</td></tr> <tr><td>C</td><td>3</td><td>A, B</td></tr> <tr><td>D</td><td>9</td><td>A</td></tr> <tr><td>E</td><td>4</td><td>A, B</td></tr> <tr><td>F</td><td>2</td><td>A, B</td></tr> <tr><td>G</td><td>2</td><td>E, H</td></tr> <tr><td>H</td><td>3</td><td>C, F</td></tr> <tr><td>I</td><td>5</td><td>D, G</td></tr> <tr><td>J</td><td>6</td><td>E, H</td></tr> <tr><td>K</td><td>10</td><td>C, F</td></tr> <tr><td>L</td><td>4</td><td>I</td></tr> <tr><td>M</td><td>12</td><td>I</td></tr> <tr><td>N</td><td>6</td><td>J, K, L</td></tr> </tbody> </table>	Activity	Duration	Predecessors	A	6	-	B	5	-	C	3	A, B	D	9	A	E	4	A, B	F	2	A, B	G	2	E, H	H	3	C, F	I	5	D, G	J	6	E, H	K	10	C, F	L	4	I	M	12	I	N	6	J, K, L	B1	Predecessors correct for A to F (entries for A and B may be blank)	[3]
		Activity	Duration	Predecessors																																														
		A	6	-																																														
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		H	3	C, F																																														
		I	5	D, G																																														
		J	6	E, H																																														
		K	10	C, F																																														
L	4	I																																																
M	12	I																																																
N	6	J, K, L																																																
M1	Substantially correct attempt at predecessors for other activities (at most 2 errors)																																																	
A1	Predecessors all correct for G to N																																																	
(ii)	Dummy is needed between 2 and 3 so that C, E and F follow both A and B but D follows A only	B1	D does not follow B (D follows A only)	[2]																																														
	Dummy is needed between 4 and 5 so that C and F do not share both a common start and a common finish	B1	Identifying C and F appropriately																																															
(iii)	<table border="1"> <thead> <tr> <th>1</th><th>2</th><th>3</th><th>4</th><th>5</th><th>6</th><th>7</th><th>8</th><th>9</th><th>10</th> </tr> </thead> <tbody> <tr> <td>0</td><td>6</td><td>6</td><td>9</td><td>9</td><td>12</td><td>15</td><td>20</td><td>24</td><td>32</td> </tr> <tr> <td>0</td><td>6</td><td>7</td><td>10</td><td>10</td><td>13</td><td>15</td><td>20</td><td>26</td><td>32</td> </tr> </tbody> </table> <p>Minimum project completion time = 32 minutes Critical activities: A, D, I and M</p>	1	2	3	4	5	6	7	8	9	10	0	6	6	9	9	12	15	20	24	32	0	6	7	10	10	13	15	20	26	32	B1	Early event times correct, in table	[5]																
		1	2	3	4	5	6	7	8	9	10																																							
		0	6	6	9	9	12	15	20	24	32																																							
		0	6	7	10	10	13	15	20	26	32																																							
		M1	Substantially correct backwards pass (at most 2 errors in total)																																															
A1	Late event times correct, in table																																																	
B1	32, cao																																																	
B1	A, D, I, M and no others, cao																																																	
(iv)	<p>Early event time at 9 becomes the larger of 24 and $9+x$</p> <p>Early event time at 10 becomes the larger of 32 and $15+x$, which then also becomes the late event time at 10</p> <p>Late event time at 9 then becomes 26 or $9+x$</p>	M1	$9+x$	[4]																																														
		A1	Larger of 24 and $9+x$																																															
		M1	Considering the event times at 10																																															
		A1	Correct consideration of 26 and $9+x$																																															
(v)	$x = 17$	B1	17	[1]																																														
			Total =	15																																														

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