

Mathematics

Advanced GCE

Unit **4737**: Decision Mathematics 2

Mark Scheme for January 2012

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This mark scheme is published as an aid to teachers and students, to indicate the requirements of the examination. It shows the basis on which marks were awarded by examiners. It does not indicate the details of the discussions which took place at an examiners' meeting before marking commenced.

All examiners are instructed that alternative correct answers and unexpected approaches in candidates' scripts must be given marks that fairly reflect the relevant knowledge and skills demonstrated.

Mark schemes should be read in conjunction with the published question papers and the report on the examination.

OCR will not enter into any discussion or correspondence in connection with this mark scheme.

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Annotations and abbreviations

Annotation in scoris	Meaning
✓ and ✗	
BOD	Benefit of doubt
FT	Follow through
ISW	Ignore subsequent working
M0, M1	Method mark awarded 0, 1
A0, A1	Accuracy mark awarded 0, 1
B0, B1	Independent mark awarded 0, 1
SC	Special case
^	Omission sign
MR	Misread
Highlighting	
Other abbreviations in mark scheme	Meaning
E1	Mark for explaining
M1 dep*	Method mark dependent on a previous mark, indicated by *
cao	Correct answer only
oe	Or equivalent
soi	Seen or implied
www	Without wrong working

Subject-specific Marking Instructions for GCE Mathematics Decision strand

- a Annotations should be used whenever appropriate during your marking.

The A, M and B annotations must be used on your standardisation scripts for responses that are not awarded or full marks. It is vital that you annotate standardisation scripts fully to show how the marks have been awarded.

For subsequent marking you must make it clear how you have arrived at the mark you have awarded.

- b An element of professional judgement is required in the marking of any written paper. Remember that the mark scheme is designed to assist in marking incorrect solutions. Correct *solutions* leading to correct answers are awarded full marks but must not be judged on the answer alone, and answers that are given in the question, especially, must be validly obtained. Steps in the working must always be looked at and anything unfamiliar must be investigated thoroughly.

Correct but unfamiliar or unexpected methods are often signalled by a correct result following an *apparently* incorrect method. Such work must be carefully assessed. When a candidate adopts a method which does not correspond to the mark scheme, award marks according to the spirit of the basic scheme; if you are in any doubt whatsoever (especially if several mark candidates are involved) you should contact your Team Leader.

- c The following types of marks are available.

M

A suitable method has been selected and *applied* in a manner which shows that the method is essentially understood. Accuracy marks are not usually lost for numerical errors, algebraic slips or errors in units. However, it is not usually sufficient for a candidate just to indicate an intention of using some method or just to quote a formula; the formula or idea must be applied to the specific problem in hand, eg by substituting the relevant quantities into the formula. In some cases the nature of the mark allowed for the award of an M mark may be specified.

A

Accuracy mark, awarded for a correct answer or intermediate step correctly obtained. Accuracy marks cannot be given unless the associated Method mark is earned (or implied). Therefore M0 A1 cannot ever be awarded.

B

Mark for a correct result or statement independent of Method marks.

Unless otherwise indicated, marks once gained cannot subsequently be lost, eg wrong working following a correct answer is ignored. Sometimes this is reinforced in the mark scheme by the abbreviation isw. However, this does not apply in the case where a candidate passes through the correct answer as part of a wrong argument.

- d When a part of a question has two or more 'method' steps, the M marks are in principle independent unless the scheme specifically says otherwise; and similarly where there are several B marks allocated. (The notation 'dep **' is used to indicate that a particular mark is dependent on an earlier, asterisked, mark in the scheme.) Of course, in practice it may happen when a candidate has once gone wrong in a part of a question, the work from there on is worthless so that no more marks can sensibly be given. On the other hand, when two or more steps are successfully run together by the candidate, the earlier marks are implied and full credit must be given.
- e The abbreviation ft implies that the A or B mark indicated is allowed for work correctly following on from previously incorrect results. Otherwise, A and B marks are given for correct work only — differences in notation are of course permitted. Accuracy (accuracy) marks are not given for answers obtained from incorrect working. When A or B marks are awarded for work at an intermediate stage of a solution, there may be various alternatives that are equally acceptable. In such cases, exactly what is acceptable will be detailed in the mark scheme rationale. If this is not the case please consult your Team Leader.

Sometimes the answer to one part of a question is used in a later part of the same question. In this case, A marks will be given 'follow through'. In such cases you must ensure that you refer back to the answer of the previous part question even if it is not shown within the image zone. You may find it easier to mark follow through questions candidate-by-candidate rather than question-by-question.

- f Wrong or missing units in an answer should not lead to the loss of a mark unless the scheme specifically indicates otherwise. Candidates are expected to give numerical answers to an appropriate degree of accuracy, with 3 significant figures often being the norm. Small variations in the degree of accuracy to which an answer is given (e.g. 2 or 4 significant figures where 3 is expected) should not normally be penalised, while answers which are grossly over- or under-specified should normally result in the loss of a mark. The situation regarding any particular cases where the accuracy of the answer may be a marking issue should be detailed in the mark scheme rationale. If in doubt, contact your Team Leader.
- g Rules for replaced work

If a candidate attempts a question more than once, and indicates which attempt he/she wishes to be marked, then examiners should do as the candidate requests.

If there are two or more attempts at a question which have not been crossed out, examiners should mark what appears to be the last (complete) attempt and ignore the others.

NB Follow these maths-specific instructions rather than those in the assessor handbook.

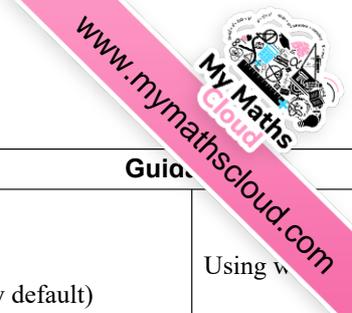
- h For a *genuine* misreading (of numbers or symbols) which is such that the object and the difficulty of the question are unaltered, mark according to the scheme but following through from the candidate's data. A penalty is then applied, generally appropriate, though this may differ for some units. This is achieved by withholding one A mark in the question.

Note that a miscopy of the candidate's own working is not a misread but an accuracy error.

Question		Answer	Marks	Guidance	
1	(i)		B1	Bipartite graph correct May show evidence of film types as well	Ignore labels attached to an additional path
1	(ii)	$N = S - J = V$ $J = V, K = U, L = T, N = S$	M1 A1	This alternating path written down, not just read off from labels on graph, do NOT condone if done in part (iii) This matching written down in words or letters	Allow $NS - SJ$ May be implied <u>and</u> matching cao
1	(iii)	$W = K - U = M$ $J = V, K = W, L = T, M = U, N = S$	B1 B1	This alternating path written down, not just read off from labels on graph This matching written down in words or symbols	Allow $WK - KU$ Not implied for Not ft cao
1	(iv)	N can only pair with S so J must pair with V Hence L can only pair with T and M with U So K pairs with W	B1	Evidence of $N - S - J - V$ and $W - K - U - M - T - L$, but NOT just repeating the complete matching already found	W can only pair with M , hence leaving V to pair with N W can only pair with M so J must pair with U

Question		Answer	Marks	Guidance
2	(i)		M1 A1	<p>Correct structure, even with unnecessary dummies (ie precedences are correct) even with directions implied. Arcs must be labelled <i>A, B, C, ...</i></p> <p>Correct structure with no unnecessary dummies, using directed arcs labelled <i>A, B, C, ...</i></p>
2	(ii)	<p>Min completion time = 360 minutes</p> <p>Critical activities: <i>A, B, D, E, H, I</i></p>	M1 M1 A1 B1 B1	<p>ft their network ft their network cao from a co unnecessary c cao, <u>with unit</u> cao</p>
2	(iii)		M1 A1	<p>Duration = 360 needed through 20 mins cao Scale on verti cao</p>
2	(iv)	<p>Move <i>C</i> to start at 150 mins, hence 150</p> <p>Painting the ceiling (<i>G</i>) could happen at the same time as hang wallpaper (<i>C</i>) and paint feature wall (<i>D</i>) or at the same time as paint woodwork (<i>E</i>)</p>	B1 B1	<p>150 Need all three</p>

Question	Answer	Marks	Guidance																																																																																									
3 (i)	<p>Add a dummy column of equal values</p> <p>Subtract all values from a constant (eg 100)</p> <table border="1" data-bbox="438 280 758 436"> <tr><td></td><td>P</td><td>R</td><td>S</td><td>X</td></tr> <tr><td>B</td><td>20</td><td>0</td><td>80</td><td>100</td></tr> <tr><td>C</td><td>60</td><td>65</td><td>40</td><td>100</td></tr> <tr><td>G</td><td>40</td><td>55</td><td>70</td><td>100</td></tr> <tr><td>H</td><td>80</td><td>0</td><td>20</td><td>100</td></tr> </table> <p>Reduce rows</p> <table border="1" data-bbox="454 492 742 616"> <tr><td>20</td><td>0</td><td>80</td><td>100</td></tr> <tr><td>20</td><td>25</td><td>0</td><td>60</td></tr> <tr><td>0</td><td>15</td><td>30</td><td>60</td></tr> <tr><td>80</td><td>0</td><td>20</td><td>100</td></tr> </table> <p>And then columns</p> <table border="1" data-bbox="470 672 758 795"> <tr><td>20</td><td>0</td><td>80</td><td>40</td></tr> <tr><td>20</td><td>25</td><td>0</td><td>0</td></tr> <tr><td>0</td><td>15</td><td>30</td><td>0</td></tr> <tr><td>80</td><td>0</td><td>20</td><td>40</td></tr> </table> <p>Cross through zeros</p> <table border="1" data-bbox="470 862 758 985"> <tr><td>20</td><td>0</td><td>80</td><td>40</td></tr> <tr><td>20</td><td>25</td><td>0</td><td>0</td></tr> <tr><td>0</td><td>15</td><td>30</td><td>0</td></tr> <tr><td>80</td><td>0</td><td>20</td><td>40</td></tr> </table> <p>Augment by 20</p> <table border="1" data-bbox="438 1041 758 1164"> <tr><td>0</td><td>0</td><td>60</td><td>20</td></tr> <tr><td>20</td><td>45</td><td>0</td><td>0</td></tr> <tr><td>0</td><td>35</td><td>30</td><td>0</td></tr> <tr><td>60</td><td>0</td><td>0</td><td>20</td></tr> </table>		P	R	S	X	B	20	0	80	100	C	60	65	40	100	G	40	55	70	100	H	80	0	20	100	20	0	80	100	20	25	0	60	0	15	30	60	80	0	20	100	20	0	80	40	20	25	0	0	0	15	30	0	80	0	20	40	20	0	80	40	20	25	0	0	0	15	30	0	80	0	20	40	0	0	60	20	20	45	0	0	0	35	30	0	60	0	0	20	<p>B1</p> <p>B1</p> <p>M1</p> <p>M1</p> <p>A1</p> <p>M1</p> <p>A1</p>	<p>Using a dummy column of equal values</p> <p>Subtracting all values from a constant and achieving an initial matrix with no negative values</p> <p>Dummy column in initial matrix can have any non-negative value, provided that it is the same throughout</p> <p>Reducing rows (method correct) (may be implied by achieving a correct reduced cost matrix before augmenting) No errors for <u>their</u> matrix</p> <p>Reducing columns (method correct) (may be implied by achieving a correct reduced cost matrix before augmenting) No errors for <u>their</u> matrix</p> <p>A correct reduced cost matrix (cao)</p> <p>Crossing through 0's using min number of lines and augmenting by min uncovered value (method correct, including entries crossed out twice) Condoned at most one wrong value</p> <p>Correct augmented matrix (may be achieved after recovery from earlier errors but must only have augmented once)</p>
	P	R	S	X																																																																																								
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Question		Answer	Marks	Guidance																												
		<p>Either $B = P$ $C = S$ G is innocent $H = R$</p> <p>Or $B = R$ C is innocent $G = P$ $H = S$</p>	<p>B1 First solution (may imply innocent by default)</p> <p>B1 Second solution (may imply innocent by default)</p>	<p>Using w</p> <p>Using words Allow B for sa for pearl neck</p>																												
3	(ii)	<p>Remove row for B and column for S</p> <table border="1" style="margin-left: auto; margin-right: auto;"> <tr> <td></td> <td>P</td> <td>R</td> <td>X</td> </tr> <tr> <td>C</td> <td>60</td> <td>65</td> <td>100</td> </tr> <tr> <td>G</td> <td>40</td> <td>55</td> <td>100</td> </tr> <tr> <td>H</td> <td>80</td> <td>0</td> <td>100</td> </tr> </table> <p>Using least values in P and R columns $G = P$ and $H = R$</p> <p>So C is innocent</p>		P	R	X	C	60	65	100	G	40	55	100	H	80	0	100	<p>B1 A valid explanation (eg achieving this matching)</p> <p>However, 'without S column, Cook's only 0 is in dummy' is not enough for first B1 <u>unless</u> G and H are also considered</p> <p>B1 Cook is innocent</p>	<p>Or work thro columns (no a needed):</p> <table border="1" style="margin-left: auto; margin-right: auto;"> <tr> <td>60</td> <td>65</td> </tr> <tr> <td>40</td> <td>55</td> </tr> <tr> <td>80</td> <td>0</td> </tr> </table> <p>Or:</p> <table border="1" style="margin-left: auto; margin-right: auto;"> <tr> <td>20</td> <td>65</td> </tr> <tr> <td>0</td> <td>55</td> </tr> <tr> <td>40</td> <td>0</td> </tr> </table> <p>In words or sy</p>	60	65	40	55	80	0	20	65	0	55	40	0
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Question			Answer	Marks	
4	(i)	(a)	$20 + 25 + 45 = 90$ cars per minute	B1	90
4	(i)	(b)	$25 + 20 + 25 + 30 = 100$ cars per minute	B1	100
4	(i)	(c)	Maximum flow ≤ 90 cars per minute	B1	≤ 90 (condone $<$)
4	(ii)		S and T are in the same set	B1	S must be in one set and T in the other
4	(iii)		Can travel either way	B1	Two-way flow 'Can travel D to E or E to D '
4	(iv)		The maximum that can travel along BC is 30 so this is the max that can go along CF	B1	$BC = 30$ (or $AB = 40$) specifically referred to
4	(v)	(a)		M1 A1	$BC = 30, CF = 30$ and $FT = 60$ This flow shown on diagram (cao)
4	(v)	(b)	<p>Cut $\{S, A\}, \{B, C, D, E, F, T\}$</p> <p>Maximum flow = minimum cut Flow = 60 and cut = 60 (so this is max flow)</p> <p>Max flow \geq this flow = 60 = this cut \geq min cut 60 = this flow \leq max flow \leq min cut \leq this cut = 60</p>	M1 A1	<p>This cut identified or drawn (on (a)) or equivalent in a description Cut through AD, AB</p> <p>Allow finding cut then saying that (in the flow) arcs AD, AB are saturated (so no more can flow)</p> <p>Allow 'cut = 60 and max flow = min cut so flow shown is max</p>
4	(vi)		<p>For $0 \leq x \leq 30$, max flow = $60 + x$</p> <p>For $x > 30$, max flow = 90</p>	M1 A1 B1	<p>$60 + x$</p> <p>$x \leq 30$ (or $x < 30$)</p> <p>90 is max</p>

Question		Answer	Marks	
5	(i)		M1 A1	May be drawn in reverse (Stage; state) labels used correctly Graph structure correct (ignore whether arcs are directed or undirected) Arcs weighted correctly
5	(ii) (a)	This row represents the transition from (0; 0) to (1; 1)	B1	State 1 in next stage
5	(ii) (b)	45 = weight of the transition from (0; 0) to (1; 1) 35 is the suboptimal minimax value from (1; 1)	B1 B1	(0; 0) to (1; 1) minimax from (1; 1)
5	(iii)	<i>C</i> and <i>D</i> or (1; 1) and (2; 0) From stage (0; 0), the suboptimal minimax corresponds to action 1 \Rightarrow (1; 1) From stage (1; 1), the suboptimal minimax corresponds to action 0 \Rightarrow (2; 0)	B1 B1	<i>C</i> and <i>D</i> or (1; 1) and (2; 0) Explaining the connection between <u>action for minimax</u> and <u>state for next stage</u> Need both cases
5	(iv) (a)	<i>J</i>	B1	Accept ' <i>J</i> or <i>K</i> '
5	(iv) (b)	Friday = <i>G</i> Thursday = <i>D</i> Wednesday = <i>B</i>	M1 A1	Accept 'at least <i>G</i> ' cao

Question		Answer	Marks																																																																	
5	(v)	Wednesday $B = (1; 0)$ or $C = (1; 1)$ Thursday $D = (2; 0), E = (2; 1)$ or $F = (2; 2)$	M1	Wednesday and Thursday correct May imply days from stage labels																																																																
		Friday $G = (3; 0)$ or $H = (3; 1)$ Saturday $J = (4; 0)$ or $K = (4; 1)$	A1	All correct and I excluded May imply days from stage labels																																																																
			A1	Appropriate allocation of (stage; state) labels, or clear statement of stage = ... , state = ...																																																																
5	(vi)	<table border="1" style="width: 100%; border-collapse: collapse; text-align: center;"> <thead> <tr> <th>Stage</th> <th>State</th> <th>Action</th> <th>Working</th> <th>Suboptimal minimax</th> </tr> </thead> <tbody> <tr> <td rowspan="2">4</td> <td>0</td> <td>0</td> <td>15</td> <td>15</td> </tr> <tr> <td>1</td> <td>0</td> <td>5</td> <td>5</td> </tr> <tr> <td rowspan="3">3</td> <td>0</td> <td>0</td> <td>$\max(45, 15)$</td> <td>45</td> </tr> <tr> <td rowspan="2">1</td> <td>0</td> <td>$\max(35, 15)$</td> <td rowspan="2">35</td> </tr> <tr> <td>1</td> <td>$\max(45, 5)$</td> </tr> <tr> <td rowspan="5">2</td> <td>0</td> <td>0</td> <td>$\max(45, 45)$</td> <td>45</td> </tr> <tr> <td rowspan="2">1</td> <td>0</td> <td>$\max(33, 45)$</td> <td rowspan="2">43</td> </tr> <tr> <td>1</td> <td>$\max(43, 35)$</td> </tr> <tr> <td rowspan="2">2</td> <td>0</td> <td>$\max(30, 45)$</td> <td rowspan="2">40</td> </tr> <tr> <td>1</td> <td>$\max(40, 35)$</td> </tr> <tr> <td rowspan="4">1</td> <td>0</td> <td>0</td> <td>$\max(50, 45)$</td> <td>50</td> </tr> <tr> <td rowspan="3">1</td> <td>0</td> <td>$\max(35, 45)$</td> <td rowspan="3">45</td> </tr> <tr> <td>1</td> <td>$\max(47, 43)$</td> </tr> <tr> <td>2</td> <td>$\max(50, 40)$</td> </tr> <tr> <td>0</td> <td>0</td> <td>0</td> <td>$\max(30, 50)$</td> <td rowspan="2">45</td> </tr> <tr> <td></td> <td></td> <td>1</td> <td>$\max(45, 45)$</td> </tr> </tbody> </table> <p>45 miles Stay at C, D, G and J</p>	Stage	State	Action	Working	Suboptimal minimax	4	0	0	15	15	1	0	5	5	3	0	0	$\max(45, 15)$	45	1	0	$\max(35, 15)$	35	1	$\max(45, 5)$	2	0	0	$\max(45, 45)$	45	1	0	$\max(33, 45)$	43	1	$\max(43, 35)$	2	0	$\max(30, 45)$	40	1	$\max(40, 35)$	1	0	0	$\max(50, 45)$	50	1	0	$\max(35, 45)$	45	1	$\max(47, 43)$	2	$\max(50, 40)$	0	0	0	$\max(30, 50)$	45			1	$\max(45, 45)$	M1	Follow through from their appropriate labelling
		Stage	State	Action	Working	Suboptimal minimax																																																														
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0	0	0	$\max(30, 50)$	45																																																																
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M1	Suboptimal minimax values correct for stages 4 and 3																																																																			
M1	Suboptimal minimax values correct for stage 2																																																																			
A1	Suboptimal minimax values correct for stages 1 and 0																																																																			
M1	45 (cao)																																																																			
A1	C, D, G, J - not as (stage; state)																																																																			

Question		Answer	Marks																		
6	(i)	<table border="1" style="margin-left: auto; margin-right: auto;"> <tr><td>4</td><td>-1</td><td>1</td><td>-2</td></tr> <tr><td>1</td><td>3</td><td>-1</td><td>1</td></tr> <tr><td>5</td><td>1</td><td>2</td><td>-1</td></tr> <tr><td>0</td><td>-1</td><td>1</td><td>1</td></tr> </table> <p style="text-align: center;">col max 5 3 2 1</p> <p>Play-safe for Colin is <i>T</i> If Colin plays <i>T</i> he can win at most 2 points</p>	4	-1	1	-2	1	3	-1	1	5	1	2	-1	0	-1	1	1	M1 A1 B1	Column maxima (or their negatives) shown <i>T</i> written down (cao) 2 (www)	All correct convincing ft their pl $N = 0, P =$
4	-1	1	-2																		
1	3	-1	1																		
5	1	2	-1																		
0	-1	1	1																		
6	(ii)	<i>W</i> is dominated by <i>Y</i> Rowena always wins more by choosing <i>Y</i>	B1	<i>Y</i> dominates or <i>Y</i> is <u>always</u> better	$5 > 4, 1 >$ all correct																
6	(iii)	Remove row for <i>W</i> , then add 1 throughout to remove negative values <table border="1" style="margin-left: auto; margin-right: auto;"> <tr><td>2</td><td>4</td><td>0</td><td>2</td></tr> <tr><td>6</td><td>2</td><td>3</td><td>0</td></tr> <tr><td>1</td><td>0</td><td>2</td><td>2</td></tr> </table> If Colin chooses <i>N</i> then Rowena can expect to win $2x + 6y + z$ points	2	4	0	2	6	2	3	0	1	0	2	2	B1 B1	Remove <i>W</i> row (first row) and add 1 to values This table written out \Rightarrow B1 'Add 1 throughout' \Rightarrow B1 <i>N</i> column (first column) identified eg 1, 5, 0	May imply Not (1+1) <i>N</i>				
2	4	0	2																		
6	2	3	0																		
1	0	2	2																		
6	(iv)	$2x + 6y + z = 2.3$ $4x + 2y = 1.6$ $3y + 2z = 1.6$ $2x + 2z = 1.6$ $m \leq 2.3$ and $m \leq 1.6 \Rightarrow$ maximum for <i>m</i> is 1.6 and so maximum for <i>M</i> is 0.6	M1 A1	Achieving 2.3 and 1.6 three times Correct explanation of why maximum value for <i>m</i> is 1.6 (0.6 is given in the question)	A statement used rather of 2.3, 1.6 $m \leq 1.6$ w Or equivalent May imply ...'																

Question		Answer	Marks													
6	(v)	Colin wins the negatives of the values in the table, so, removing row W gives	B1	Colin's winnings are negatives of values in table												
		<table border="1" style="margin-left: auto; margin-right: auto;"> <tr> <td>-1</td> <td>-3</td> <td>1</td> <td>-1</td> </tr> <tr> <td>-5</td> <td>-1</td> <td>-2</td> <td>1</td> </tr> <tr> <td>0</td> <td>1</td> <td>-1</td> <td>-1</td> </tr> </table>	-1	-3	1	-1	-5	-1	-2	1	0	1	-1	-1		May also remove column N
		-1	-3	1	-1											
-5	-1	-2	1													
0	1	-1	-1													
If Rowena chooses row X then Colin can expect to win $-3p + q - t$ Rowena's optimum is to win 0.6 points so Colin's is to lose 0.6 points	M1	Relating $-3p + r - t$ to the X row	Enough to													
A1	Explaining why expression equals -0.6	'Rowena														
6	(vi)	$p = 0.2$ $q = 0.4$ and $t = 0.4$	M1 A1	cao cao												

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