

GCE

Mathematics

Unit **4737**: Decision Mathematics 2

Advanced GCE

Mark Scheme for June 2018

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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.

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Annotations, (including abbreviations), including those used in scoris, which are used when marking.

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
M1 dep*	Method mark dependent on a previous mark, indicated by *
cao	Correct answer only
oe	Or equivalent
rot	Rounded or truncated
soi	Seen or implied
www	Without wrong working

Subject specific instructions for this question paper

- 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 either 0 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 work must not be judged on the answer alone, and answers that are given in the question, especially, must be validly obtained; key 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 marks or 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. Method 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 errors 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 form of answer is ignored. Sometimes this is reinforced in the mark scheme by the abbreviation isw. However, this would not apply to a 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 that 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. A (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 often be 'follow through'. In such cases you must ensure that you refer back to the answer of the previous part question even if this 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

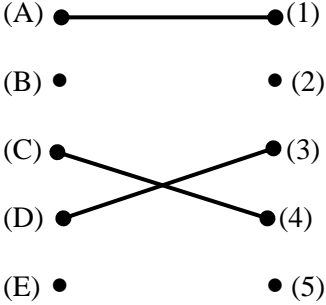
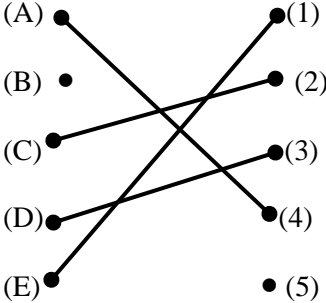
If a candidate attempts a question more than once, and indicates which attempt he/she wishes to be marked, then examiners should do as the candidate requests.

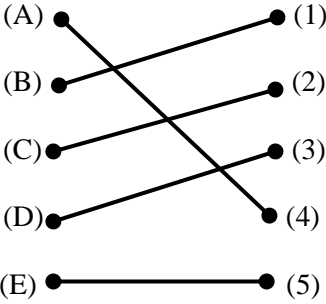
If there are two or more attempts at a question which have not been crossed out, examiners should mark what appears to be the last (complete) attempt and ignore the others.

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

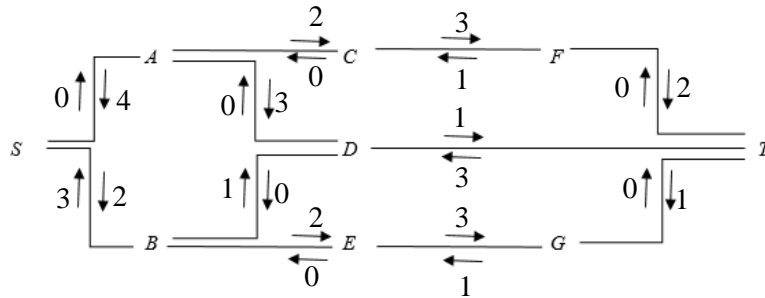
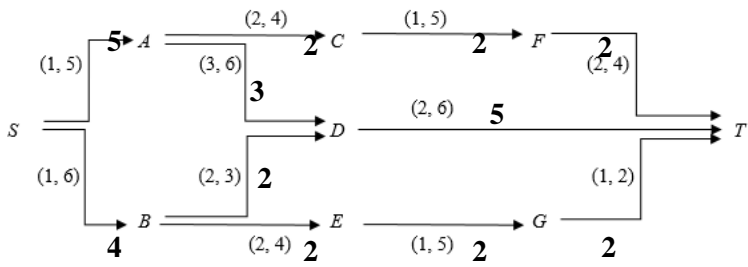
- h For a *genuine* misreading (of numbers or symbols) which is such that the object and the difficulty of the question remain unaltered, mark according to the scheme but following through from the candidate's data. A penalty is then applied; 1 mark is generally appropriate, though this may differ for 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/Indicative content	Mark	Guidance
1 (i)		<p>B1</p> <p>[1]</p>	<p>For reference: (1) = carrot and houmous, (2) = cheddar and pickle, (3) = chicken and stuffing, (4) = cream cheese, (5) = crab</p> <p>Arcs A-1, C-4 and D-3 (and no other arcs) Must be in the space for (i)</p>
(ii)	<p>(E) = (1) – (A) = (4) – (C) = (2)</p> 	<p>B1</p> <p>B1</p> <p>[2]</p>	<p>This alternating path in this order (accept any notation)</p> <p>This matching drawn Must be in the space for (ii)</p>

Question	Answer/Indicative content	Mark	Guidance
(iii)	$(5) = (D) - (3) = (B)$ $(A) = (4) \quad (B) = (3) \quad (C) = (2) \quad (D) = (5) \quad (E) = (1)$	B1 B1 [2]	This alternating path in this order (accept any notation) This matching listed Accept any notation. Must be in the space for (iii)
(iv)		B1 [1]	This complete matching drawn Must be in the space for (iv)

Question	Answer/Indicative content	Mark	Guidance
2 (i)	The minimum flow out of A is $(2 + 3 =) 5$ AC must be at least 2 and AD must be at least 3	B1 [1]	Using flow 'out of A' or 'AC and AD' <u>and</u> using '5' or '2 and 3'
(ii)	Flow in FT = flow in CF = flow in AC = 2 (from part (i))	B1 [1]	Making the connection between FT and AC <u>and</u> using 2
(iii)	(a)	B1 [1]	This flow indicated in an appropriate way
	(b)	M1 A1	At least one correct pair (e.g. 0, 4) before augmenting Allow all directions reversed, assume a blank means 0 All correct
	(c)	B1 B1	Values augmented for their route This route written (or in reverse) Accept arcs written provided they are given in the correct order, with no extra arcs
	(d)	B1 [5]	Cut through arcs SA, BD and GT described in any way If no written answer allow cut drawn on diagram, provided it is obvious



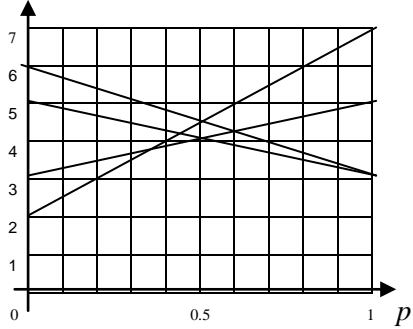
Question		Answer/Indicative content	Mark	Guidance																																																																																																			
3	(i)	<table border="1"> <thead> <tr> <th></th> <th>N</th> <th>P</th> <th>E</th> <th>B</th> </tr> </thead> <tbody> <tr> <td>(1)</td> <td>0</td> <td>4</td> <td>8</td> <td>8</td> </tr> <tr> <td>(2)</td> <td>2</td> <td>5</td> <td>7</td> <td>8</td> </tr> <tr> <td>(3)</td> <td>5</td> <td>6</td> <td>7</td> <td>9</td> </tr> <tr> <td>(4)</td> <td>0</td> <td>7</td> <td>6</td> <td>8</td> </tr> </tbody> </table>		N	P	E	B	(1)	0	4	8	8	(2)	2	5	7	8	(3)	5	6	7	9	(4)	0	7	6	8	B1 B1 [2]	Mark final attempt only Convert from minimisation to maximisation (e.g. subtract values from 1000) to give non-negative values Reduce entries to single figures (by dividing by 100) Or equivalent by reducing and then converting																																																																										
		N	P	E	B																																																																																																		
(1)	0	4	8	8																																																																																																			
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(ii)	<p>Rows reduced</p> <table border="1"> <thead> <tr> <th></th> <th>N</th> <th>P</th> <th>E</th> <th>B</th> </tr> </thead> <tbody> <tr> <td>(1)</td> <td>0</td> <td>4</td> <td>8</td> <td>8</td> </tr> <tr> <td>(2)</td> <td>0</td> <td>3</td> <td>5</td> <td>6</td> </tr> <tr> <td>(3)</td> <td>0</td> <td>1</td> <td>2</td> <td>4</td> </tr> <tr> <td>(4)</td> <td>0</td> <td>7</td> <td>6</td> <td>8</td> </tr> </tbody> </table> <p>Cols reduced</p> <table border="1"> <thead> <tr> <th></th> <th>N</th> <th>P</th> <th>E</th> <th>B</th> </tr> </thead> <tbody> <tr> <td>(1)</td> <td>0</td> <td>3</td> <td>6</td> <td>4</td> </tr> <tr> <td>(2)</td> <td>0</td> <td>2</td> <td>3</td> <td>2</td> </tr> <tr> <td>(3)</td> <td>0</td> <td>0</td> <td>0</td> <td>0</td> </tr> <tr> <td>(4)</td> <td>0</td> <td>6</td> <td>4</td> <td>4</td> </tr> </tbody> </table> <p>Augment by 2</p> <table border="1"> <thead> <tr> <th></th> <th>N</th> <th>P</th> <th>E</th> <th>B</th> </tr> </thead> <tbody> <tr> <td>(1)</td> <td>0</td> <td>1</td> <td>4</td> <td>2</td> </tr> <tr> <td>(2)</td> <td>0</td> <td>0</td> <td>1</td> <td>0</td> </tr> <tr> <td>(3)</td> <td>2</td> <td>0</td> <td>0</td> <td>0</td> </tr> <tr> <td>(4)</td> <td>0</td> <td>4</td> <td>2</td> <td>2</td> </tr> </tbody> </table> <p>Augment by 1</p> <table border="1"> <thead> <tr> <th></th> <th>N</th> <th>P</th> <th>E</th> <th>B</th> </tr> </thead> <tbody> <tr> <td>(1)</td> <td>0</td> <td>0</td> <td>3</td> <td>1</td> </tr> <tr> <td>(2)</td> <td>1</td> <td>0</td> <td>1</td> <td>0</td> </tr> <tr> <td>(3)</td> <td>3</td> <td>0</td> <td>0</td> <td>0</td> </tr> <tr> <td>(4)</td> <td>0</td> <td>3</td> <td>1</td> <td>1</td> </tr> </tbody> </table>		N	P	E	B	(1)	0	4	8	8	(2)	0	3	5	6	(3)	0	1	2	4	(4)	0	7	6	8		N	P	E	B	(1)	0	3	6	4	(2)	0	2	3	2	(3)	0	0	0	0	(4)	0	6	4	4		N	P	E	B	(1)	0	1	4	2	(2)	0	0	1	0	(3)	2	0	0	0	(4)	0	4	2	2		N	P	E	B	(1)	0	0	3	1	(2)	1	0	1	0	(3)	3	0	0	0	(4)	0	3	1	1	M1 A1 B1 M1 A1 [5]	Reducing each row (question says to reduce rows first, but allow if columns are reduced first instead) Need to see a 0 in each row (or a 0 in each column), condone negative entries if seen, FT (their) answer to (i) Achieving this reduced cost matrix Allow scaled by 100 Evidence of covering May be implied from augmenting Augmenting by least uncovered value Need to see at least one cell 'of each type' augmented correctly Using a second augmentation to achieve this final matrix (or scaled by 100) after exactly two augmentations
	N	P	E	B																																																																																																			
(1)	0	4	8	8																																																																																																			
(2)	0	3	5	6																																																																																																			
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	N	P	E	B																																																																																																			
(1)	0	0	3	1																																																																																																			
(2)	1	0	1	0																																																																																																			
(3)	3	0	0	0																																																																																																			
(4)	0	3	1	1																																																																																																			

Question		Answer/Indicative content	Mark	Guidance
	(iii)	Event 1 = posters Event 2 = on buses Event 3 = emails Event 4 = newspapers Total number of people expected = 2100	B1 B1 [2]	1 = P 2 = B 3 = E 4 = N 2100 (not 21)
	(iv)	Adding 80 to each of these gives the same returns as for advertising on buses, so the solution would be the same (except that event 2 = leaflet drop)	B1 [1]	Evidence that the column entries differ from the given ones by a constant Reducing columns would be the same as for the original values

Question		Answer/Indicative content	Mark	Guidance																																		
4	(i)	(a)	<table border="1" style="margin-left: auto; margin-right: auto;"> <tr> <td></td> <td colspan="3" style="text-align: center;">Maya</td> <td></td> </tr> <tr> <td></td> <td style="text-align: center;">B</td> <td style="text-align: center;">F</td> <td style="text-align: center;">H</td> <td style="text-align: center;">row min</td> </tr> <tr> <td style="text-align: right;">Leo</td> <td style="text-align: center;">A</td> <td style="text-align: center;">-1</td> <td style="text-align: center;">-3</td> <td style="text-align: center;">6</td> <td style="text-align: center;">-3</td> </tr> <tr> <td></td> <td style="text-align: center;">D</td> <td style="text-align: center;">1</td> <td style="text-align: center;">-2</td> <td style="text-align: center;">-4</td> <td style="text-align: center;">-4</td> </tr> <tr> <td></td> <td style="text-align: center;">E</td> <td style="text-align: center;">2</td> <td style="text-align: center;">-1</td> <td style="text-align: center;">-4</td> <td style="text-align: center;">-4</td> </tr> <tr> <td></td> <td style="text-align: center;">col max</td> <td style="text-align: center;">2</td> <td style="text-align: center;">-1</td> <td style="text-align: center;">6</td> <td></td> </tr> </table> <p style="text-align: center;">↑</p> <p style="text-align: center;">Play-safe for Leo A Play-safe for Maya F</p>		Maya					B	F	H	row min	Leo	A	-1	-3	6	-3		D	1	-2	-4	-4		E	2	-1	-4	-4		col max	2	-1	6		<p>B1 This table with row and column labels (A, D, E and B, F, H) Need not show row minima and col maxima</p> <p>B1 Play-safe for Leo = A</p> <p>M1 Calculating column maxima (or equivalent) May be implied from a correct play-safe for Maya</p> <p>A1 Play-safe for Maya = F</p>
			Maya																																			
			B	F	H	row min																																
Leo	A	-1	-3	6	-3																																	
	D	1	-2	-4	-4																																	
	E	2	-1	-4	-4																																	
	col max	2	-1	6																																		
(b)	Maya would win 3 points	B1 ft	3 (follow through their claimed play-safe for Leo)																																			
(c)	Leo would play card E	B1 ft	E (follow through their claimed play-safe for Maya)																																			
			[6]																																			
	(ii)	(a)	Using the five columns B, C, F, G, H row minima for rows A, D, E are still -3, -4, -4 so Leo's play-safe is still A This makes no difference to Leo's play-safe choice (as given)	B1 Row min values same as before A: -1,-1,-3,-3,6 ⇒ -3; D: 1,0,-2,-3,-4 ⇒ -4; E: 2,0,-1,-2,-4 ⇒ -4																																		
		(b)	Cards B, C and H	B1 [2] B, C, H (cao)																																		
	(iii)		B because it is play-safe	B1 Least loss for Maya (lose 2 instead of 6) in worst case																																		
			F because she wins with four of the five possibilities	B1 4 negative values in column F, more than B or H (in the 5 remaining columns of original table)																																		
			H because it gives the greatest possible gain (6 instead of 4 or 3)	B1 But not using col total or mean (in any of the three parts)																																		
			<table border="1" style="margin-left: auto; margin-right: auto;"> <tr> <td style="text-align: center;">Pay-off for Maya</td> <td style="text-align: center;">B</td> <td style="text-align: center;">F</td> <td style="text-align: center;">H</td> </tr> <tr> <td style="text-align: center;">A</td> <td style="text-align: center;">1</td> <td style="text-align: center;">3</td> <td style="text-align: center;">-6</td> </tr> <tr> <td style="text-align: center;">C</td> <td style="text-align: center;">-1</td> <td style="text-align: center;">3</td> <td style="text-align: center;">-5</td> </tr> <tr> <td style="text-align: center;">D</td> <td style="text-align: center;">-1</td> <td style="text-align: center;">2</td> <td style="text-align: center;">4</td> </tr> <tr> <td style="text-align: center;">E</td> <td style="text-align: center;">-2</td> <td style="text-align: center;">1</td> <td style="text-align: center;">4</td> </tr> <tr> <td style="text-align: center;">G</td> <td style="text-align: center;">4</td> <td style="text-align: center;">-6</td> <td style="text-align: center;">6</td> </tr> <tr> <td style="text-align: center;">Min for Maya</td> <td style="text-align: center;">-2</td> <td style="text-align: center;">-6</td> <td style="text-align: center;">-6</td> </tr> </table>	Pay-off for Maya	B	F	H	A	1	3	-6	C	-1	3	-5	D	-1	2	4	E	-2	1	4	G	4	-6	6	Min for Maya	-2	-6	-6	[3]						
Pay-off for Maya	B	F	H																																			
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G	4	-6	6																																			
Min for Maya	-2	-6	-6																																			

Question		Answer/Indicative content					Mark	Guidance
5	(i)		Stage	State	Action	Working	Suboptimal maximin	
			3	0	0	4	4	
				1	0	3	3	
			2	0	0	$\min(2, 4) = 2$	3	
					1	$\min(4, 3) = 3$		
				1	0	$\min(3, 4) = 3$	3	
					1	$\min(2, 3) = 2$		
				2	0	$\min(5, 4) = 4$	4	
					1	$\min(2, 3) = 2$		
			1	0	0	$\min(2, 3) = 2$	3	
1	$\min(5, 3) = 3$							
1	1	$\min(2, 3) = 2$		2				
2	$\min(2, 4) = 2$							
0	0	0	$\min(4, 3) = 3$	3				
		1	$\min(3, 2) = 2$					
Maximin route: (0; 0) – (1; 0) – (2; 1) – (3; 0) – (4; 0)							B1 [6]	This route written in this form, including (0; 0) and (4; 0)
	(ii)		(0; 0) to (1; 0) has weight 4 (1; 0) to (2; 1) has weight 5 (2; 1) to (3; 0) has weight 3 (3; 0) to (4; 0) has weight 4 Minimum of 4, 5, 3, 4 is 3 = min weight on this route This is greater than (or equal to) min weight for all other routes No other route gives a larger minimum				B1 ft M1 A1 [3]	Arc weights correct (ft their arcs) Using their arc weights to calculate min (their 3) This is the maximum of all the route mins
	(iii)	(a)	Maximum path				B1	Maximising, longest path, greatest total weight, or equivalent
		(b)	Route: (0; 0) – (1; 0) – (2; 1) – (3; 0) – (4; 0)				B1	This route written in this form, including (0; 0) and (4; 0), (cao)
		(c)	4+5+3+4 = 16, no other route gives a larger total				B1 [3]	(Their) 16 or (their) 4+5+3+4 <u>and</u> reference to maximum

Question		Answer/Indicative content	Mark	Guidance															
6	(i)	Property 1: two opposing teams or players	B1	Explaining two-person ('two players' or 'two teams' or equivalent) Explaining zero-sum Simultaneous play Do not know what the other side will do when choices are made															
		Property 2: what one player gains the other loses	B1																
		Property 3: play simultaneously, rather than taking turns	B1																
	(ii)	Val should not play in the final because for <u>each</u> topic Val's score is lower than Wesley's	M1 A1	Val or V Dominance ($W > V$) in <u>each</u> column (or shown numerically) Wesley's score is <u>always</u> better than Val's															
				<table border="1"> <tr> <td>V</td> <td>2</td> <td>4</td> <td>1</td> <td>4</td> </tr> <tr> <td>W</td> <td>3</td> <td>5</td> <td>2</td> <td>6</td> </tr> </table>	V	2	4	1	4	W	3	5	2	6					
V	2	4	1	4															
W	3	5	2	6															
	(iii)	Famous faces = $3 + 2p$ Films = $5 - 2p$ Food = $2 + 5p$ Football = $6 - 3p$	M1 M1 A1 ft	Any correct expression using U and W <u>or</u> U and V, need not be simplified but must have p as the only variable <table style="width: 100%; border: none;"> <tr> <td></td> <td style="text-align: center;">U and W</td> <td style="text-align: center;">U and V</td> </tr> <tr> <td>i.e. famous faces</td> <td>$5p + 3(1 - p)$ or $3 + 2p$</td> <td>$5p + 2(1 - p)$ or $2 + 3p$</td> </tr> <tr> <td>films</td> <td>$3p + 5(1 - p)$ or $5 - 2p$</td> <td>$3p + 4(1 - p)$ or $4 - p$</td> </tr> <tr> <td>food</td> <td>$7p + 2(1 - p)$ or $2 + 5p$</td> <td>$7p + (1 - p)$ or $1 + 6p$</td> </tr> <tr> <td>football</td> <td>$3p + 6(1 - p)$ or $6 - 3p$</td> <td>$3p + 4(1 - p)$ or $4 - p$</td> </tr> </table> Any correct expression, for U and W <u>or</u> U and V, in the form $a+bp$ All four correct and simplified, ft their row rejected from part (ii)		U and W	U and V	i.e. famous faces	$5p + 3(1 - p)$ or $3 + 2p$	$5p + 2(1 - p)$ or $2 + 3p$	films	$3p + 5(1 - p)$ or $5 - 2p$	$3p + 4(1 - p)$ or $4 - p$	food	$7p + 2(1 - p)$ or $2 + 5p$	$7p + (1 - p)$ or $1 + 6p$	football	$3p + 6(1 - p)$ or $6 - 3p$	$3p + 4(1 - p)$ or $4 - p$
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			[3]																

Question	Answer/Indicative content	Mark	Guidance																																																																													
(iv)	 <p data-bbox="376 619 562 651">Value of $p = 0.5$</p>	<p data-bbox="1137 347 1189 379">B1</p> <p data-bbox="1137 416 1189 448">M1</p> <p data-bbox="1137 485 1189 517">A1 ft</p> <p data-bbox="1137 619 1189 683">B1 [4]</p>	<p data-bbox="1234 347 1980 379">Horizontally 0 to 1 fills at least half the width <u>and</u> vertical scale</p> <p data-bbox="1234 416 2024 448">Four lines that cut $p = 1$ at 5, 3, 7, 3 (allow dominated line missing)</p> <p data-bbox="1234 485 2024 549">Lines cut $p = 0$ at their a values from part (iii) (or equivalent, if not simplified)</p> <p data-bbox="1234 619 1346 651">0.5 (cao)</p>																																																																													
(v)	<table border="1" data-bbox="367 719 1039 975"> <thead> <tr> <th>M</th> <th>m</th> <th>p</th> <th>q</th> <th>r</th> <th>s</th> <th>t</th> <th>u</th> <th>v</th> <th>w</th> <th>RHS</th> </tr> </thead> <tbody> <tr> <td>1</td> <td>-1</td> <td>0</td> <td>0</td> <td>0</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>1</td> <td>-5</td> <td>-2</td> <td>-3</td> <td>1</td> <td>0</td> <td>0</td> <td>0</td> <td>0</td> <td>0</td> </tr> <tr> <td>0</td> <td>1</td> <td>-3</td> <td>-4</td> <td>-5</td> <td>0</td> <td>1</td> <td>0</td> <td>0</td> <td>0</td> <td>0</td> </tr> <tr> <td>0</td> <td>1</td> <td>-7</td> <td>-1</td> <td>-2</td> <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>-3</td> <td>-4</td> <td>-6</td> <td>0</td> <td>0</td> <td>0</td> <td>1</td> <td>0</td> <td>0</td> </tr> <tr> <td>0</td> <td>0</td> <td>1</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> </tr> </tbody> </table>	M	m	p	q	r	s	t	u	v	w	RHS	1	-1	0	0	0	0	0	0	0	0	0	0	1	-5	-2	-3	1	0	0	0	0	0	0	1	-3	-4	-5	0	1	0	0	0	0	0	1	-7	-1	-2	0	0	1	0	0	0	0	1	-3	-4	-6	0	0	0	1	0	0	0	0	1	1	1	0	0	0	0	1	1	<p data-bbox="1137 756 1189 788">B1</p> <p data-bbox="1137 825 1189 857">B1</p> <p data-bbox="1137 893 1189 925">B1</p> <p data-bbox="1137 925 1189 957">B1</p> <p data-bbox="1137 1098 1189 1129">[4]</p>	<p data-bbox="1234 692 2069 724">Need not label rows or columns and rows/columns may be in any order</p> <p data-bbox="1234 756 1794 788">Objective row 1 -1 0 0 0 ... 0 in simplex tableau</p> <p data-bbox="1234 825 2047 888">Four constraint rows or written as inequalities ($m \leq 5p + 2q + 3r$ etc.) or equations with slack ($m - 5p - 2q - 3r + s = 0$ etc.)</p> <p data-bbox="1234 893 1928 925">Appropriate use of slack variables (in tableau or equations)</p> <p data-bbox="1234 925 2024 957">$p + q + r \leq 1$ or as an equation with slack (in tableau or formulation)</p> <p data-bbox="1234 994 2047 1090">If a candidate uses $p + q + r = 1$ to eliminate one of the variables they can get at most B1 B0 B1 B0 because their simplex will not be able to be used to solve the problem</p>
M	m	p	q	r	s	t	u	v	w	RHS																																																																						
1	-1	0	0	0	0	0	0	0	0	0																																																																						
0	1	-5	-2	-3	1	0	0	0	0	0																																																																						
0	1	-3	-4	-5	0	1	0	0	0	0																																																																						
0	1	-7	-1	-2	0	0	1	0	0	0																																																																						
0	1	-3	-4	-6	0	0	0	1	0	0																																																																						
0	0	1	1	1	0	0	0	0	1	1																																																																						

Question	Answer/Indicative content	Mark	Guidance																																																																																								
7 (i)		<p>M1</p> <p>M1</p> <p>A1</p> <p>[3]</p>	<p>For reference: A(20), B(15), C(20), D(10), E(10), F(20), G(50), H(20), I(10), J(20), K(20), L(30), M(10), N(5)</p> <p>Consistent but incorrect use of boxes can get at most M1, M1</p> <p>Dealing with a merge on forward pass (e.g. 20 where B, D and dummy merge), largest value at merge on forwards pass</p> <p>Dealing with merge of dummies on backwards pass, smallest value at merge on backwards pass</p> <p>All correct</p>																																																																																								
(ii)	<p>e.g.</p> <table border="1" data-bbox="293 759 1106 898"> <tr> <td>B</td><td>B</td><td>B</td><td>E</td><td>E</td><td>H</td><td>H</td><td>H</td><td>H</td><td></td><td></td><td></td><td>L</td><td>L</td><td>L</td><td>L</td><td>L</td><td></td><td></td><td></td><td></td><td>N</td> </tr> <tr> <td>D</td><td>D</td><td>C</td><td>C</td><td>C</td><td>C</td><td>I</td><td>I</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>M</td><td>M</td> </tr> <tr> <td>A</td><td>A</td><td>A</td><td>A</td><td></td><td></td><td></td><td></td><td>G</td><td>G</td><td>G</td><td>G</td><td>G</td><td>G</td><td>G</td><td>G</td><td>G</td><td>K</td><td>K</td><td>K</td><td>K</td><td></td> </tr> <tr> <td></td><td></td><td></td><td></td><td>F</td><td>F</td><td>F</td><td>F</td><td>J</td><td>J</td><td>J</td><td>J</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td> </tr> </table>	B	B	B	E	E	H	H	H	H				L	L	L	L	L					N	D	D	C	C	C	C	I	I													M	M	A	A	A	A					G	G	G	G	G	G	G	G	G	K	K	K	K						F	F	F	F	J	J	J	J											<p>B1</p> <p>B1</p> <p>B1</p> <p>B1</p> <p>[4]</p>	<p>Either activities B and D or activities C and E are completed by time 20 (when A finishes)</p> <p>Activities B, C, D, E, H, I, L, M, N are done by the two people and none of A, F, G, J, K</p> <p>M starts at time 110 and N starts at time 120</p> <p>Bottom two rows: A followed by F, G or G, F with J after F and K after G and all completed at time 110</p>
B	B	B	E	E	H	H	H	H				L	L	L	L	L					N																																																																						
D	D	C	C	C	C	I	I													M	M																																																																						
A	A	A	A					G	G	G	G	G	G	G	G	G	K	K	K	K																																																																							
				F	F	F	F	J	J	J	J																																																																																
(iii)	<p>Version 1: 140 (minutes)</p> <p>Version 2: 140 (minutes)</p>	<p>B1</p> <p>B1</p> <p>[2]</p>	<p>Time does not change</p> <p>Reduced by 15 (minutes)</p>																																																																																								

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