OCR
Oxford Cambridge and RSA

GCE

Mathematics

Unit **4737**: Decision Mathematics 2

Advanced GCE

Mark Scheme for June 2014

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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.

These are the annotations, (including abbreviations), including those used in scoris, which are used when marking

Annotation in scoris	Meaning
BP	Blank Page – this annotation must be used on all blank pages within an answer booklet (structured or unstructured) and on each page of an additional object where there is no candidate response.
✓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

Here are the 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.

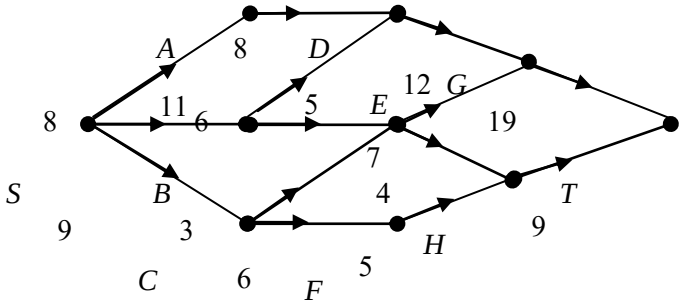
If there are two or more attempts at a question which have not been crossed out, examiners should mark what appears to be the last (complete) attempt and ignore the others.

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)		A – S – M – R – L – T Adele has the scottie dog — Adele has S Ezra has the flat iron — Ezra has F Jonah has the old boot — Jonah has O Lily has the top hat — Lily has T Molly has the racing car — Molly has R	M1 A1 **[2]**	Path that starts A – F – E – S – is longer and gets M0, any other path (including this in reverse) is wrong. Alternating path must be written down, and is not implied from a diagram or from the matching Allow 'add/remove' or 'in/out' provided path is obvious Must include Ezra and Jonah (as well as the changes) May draw a bipartite graph, but only mark written answer (using words or initial letters)
	(ii)		N – O – J – B Adele has the scottie dog — Adele has S Ezra has the flat iron — Ezra has F Jonah has the battleship — Jonah has B Lily has the top hat — Lily has T Molly has the racing car — Molly has R Noah has the old boot — Noah has O	B1 B1 **[2]**	Follow through errors from part **(i)**, if possible. Condone longer paths here, provided they are correct and join N to whichever of B and T was unmatched after **(i)** Allow 'add/remove' or 'in/out' provided path is obvious A correct complete matching (this or with A - F and E - S), whether it follows from their working or not
	(iii)		B must pair with J, so O must pair with N and T with L This means that R must pair with M So A and E are left to pair with F and S (and both of these are possible) A – S, E – F, J – B, L – T, M – R, N – O A – F, E – S, J – B, L – T, M – R, N – O	B1 B1 **[2]**	Showing that there are no more than two complete matchings (not implied from just listing the two complete matchings, need evidence to show why J, L, M and N cannot be changed, note: question says to start from B). The two complete matchings This mark could be achieved by having a valid matching in **(ii)** and then saying 'swap A and E, or 'swap S and F' or a valid matching in **(ii)** and the other matching listed here

Question			Answer/Indicative content	Mark	Guidance
2	(i)			B1 [1]	Adding directed arcs *SA*, *SB*, *SC*, *GT*, *HT* (and no others) Weights at least 8, 11, 9, 19, 9 (respectively) Allow values shown or anything larger May also see cut shown for **(ii)** or working for **(iv)**, ignore this
	(ii)	(a)	8 + 6 + 7 + 4 + 6 = 31 litres per second	B1 **[1]**	31 (cao), working need not be seen, units not necessary
	(ii)	(b)	12 + 7 + 4 + 5 = 28 litres per second	B1 **[1]**	28 (cao), working need not be seen, units not necessary
	(ii)	(c)	Maximum flow is less than or equal to 28 litres per second	B1 **[1]**	$\leq$ their smaller value oe ('at most', upper bound, max, etc) (do not accept <)
	(iii)		Showing or describing a valid flow with *DG* = 12, *BE* = 5, *CE* = 3 and *FH* = 5 12 + 5 + 3 + 5 = 25, this is the max flow through the network since cut {*S*, *A*, *B*, *C*, *D*, *F*}, {*E*, *G*, *H*, *T*} = 25	B1 M1 A1 **[3]**	Showing or describing a flow of 25 with or without supersource and supersink) Identifying any cut < 28 (if multiple cuts need correct weight or chosen cut indicated), may be done by identifying arcs *DG*, *BE*, *CE*, *FH*, for example. This cut and stating 25 (units not necessary)
	(iv)		Can increase flow through *CE* up to a maximum of 6 (increase it by up to 3) and increase the max flow correspondingly After 6, any further increase will make no difference, the maximum flow is then 28	B1 B1 **[2]**	Describing what happens up to *CE* = 6, identifying 6 as the upper value or that max useful increase to *CE* is 3 Max flow = 28 (units not necessary) (cao)

Question			Answer/Indicative content	Mark	Guidance
3	(i)		(see tables below)		

	P	R	S	T	U
G	25	50	34	40	25
H	36	42	48	44	45
I	27	50	45	42	26
J	40	46	28	45	50
K	34	48	34	50	40

Rows reduced

	P	R	S	T	U
G	0	25	9	15	0
H	0	6	12	8	9
I	1	24	19	16	0
J	12	18	0	17	22
K	0	14	0	16	6

M1 — Substantially correct attempt to reduce rows (condone at most 2 arithmetic errors, award mark even if columns have been reduced first)

Columns reduced

	P	R	S	T	U
G	0	19	9	7	0
H	0	0	12	0	9
I	1	18	19	8	0
J	12	12	0	9	22
K	0	8	0	8	6

M1 — Substantially correct attempt to reduce columns (condone at most 2 arithmetic errors (entries), award mark even if columns have been reduced first)

A1 — Correct reduced cost matrix (cao)

B1 — Crossing out 0's using exactly 4 lines

[4]

(ii)

Augment by 7

	P	R	S	T	U
G	0	12	9	0	0
H	7	0	19	0	16
I	1	11	19	1	0
J	12	5	0	2	22
K	0	1	0	1	6

continued on next page

Guidance: Follow through their reduced cost matrix if possible

M1 — Substantially correct attempt to augment by minimum uncovered element (must see at least one cell of each type augmented correctly)

A1 — Augmentation correct for their reduced cost matrix (must have augmented by the minimum uncovered element, not lots of augmentations by 1)

Candidates may have used additional tables on additional objects, or may roll their working into part **(iii)**, condone this

<table>
<tr><th colspan="2">Question</th><th>Answer/Indicative content</th><th>Mark</th><th>Guidance</th></tr>
<tr><td></td><td>(ii) cont</td><td></td><td>Gill should have the tiling
Harry should have the rewiring
Ivy should have the upholstery
James should have the shelving
Kelly should have the plastering
Total cost = £170</td><td>B1

B1
[4]</td><td>G = T
H = R
I = U
J = S
K =P
Correct allocation from 0’s in their augmented matrix (if possible)
170 (cao, not ft) (units not necessary)</td></tr>
<tr><td></td><td>(iii)</td><td></td><td>
<table>
<tr><th></th><th>P</th><th>R</th><th>S</th><th>T</th><th>U</th></tr>
<tr><td>Gill</td><td>0</td><td></td><td></td><td>(0)</td><td>0</td></tr>
<tr><td>Harry</td><td></td><td>0</td><td></td><td>0</td><td></td></tr>
<tr><td>Ivy</td><td>1</td><td></td><td></td><td>1</td><td>0</td></tr>
<tr><td>James</td><td></td><td></td><td>0</td><td></td><td></td></tr>
<tr><td>Kelly</td><td>0</td><td>1</td><td>0</td><td>1</td><td></td></tr>
</table>
<table>
<tr><th></th><th>First solution</th><th>Second solution</th><th>Third solution</th></tr>
<tr><td>Gill</td><td>P</td><td>P</td><td>U</td></tr>
<tr><td>Harry</td><td>T</td><td>R</td><td>R</td></tr>
<tr><td>Ivy</td><td>U</td><td>U</td><td>T</td></tr>
<tr><td>James</td><td>S</td><td>S</td><td>S</td></tr>
<tr><td>Kelly</td><td>R</td><td>T</td><td>P</td></tr>
</table>
</td><td>B1

M1

A1
A1
A1

[5]</td><td>Table showing positions of 0’s and 1’s (allow GT missing)
Follow through from their part (ii) if possible for this mark
condone other values shown as well (ie copying out from above)
but watch out for further augmentations or restarting with GT increased

James does S (in any of the solutions given)

First solution (cao)
Second solution (cao)
Third solution (cao) – and no more
Solutions may appear in any order</td></tr>
</table>

<table>
<tr><th colspan="3">Question</th><th>Answer/Indicative content</th><th>Mark</th><th>Guidance</th></tr>
<tr><td>4</td><td>(i)</td><td></td><td>Subtract 4 throughout (for Ross)
(or (R – C) ÷ 2, or equivalent)

Total of Ross's score and Collwen's score is 8 for each choice, subtracting 4 from each entry makes total always equal 0</td><td>B1

B1

[2]</td><td>Stating how given table is formed

Explaining why this gives zero-sum
Allow 'each cell gives total 8' but not just 'total is 8'
Allow a description of how the values in the table are formed from each of R and C, but not just 'what one gains the other loses'</td></tr>
<tr><td></td><td>(ii)</td><td></td><td>Collwen should also choose Ice</td><td>B1

[1]</td><td>Ignore any reference to numerical values
Allow I if it is obvious that this refers to Ice</td></tr>
<tr><td></td><td>(iii)</td><td></td><td><table><tr><th></th><th>F</th><th>I</th><th>G</th><th>min</th></tr><tr><td>F</td><td>–3</td><td>3</td><td>–2</td><td>–3</td></tr><tr><td>I</td><td>2</td><td>–2</td><td>0</td><td>–2</td></tr><tr><td>G</td><td>1</td><td>–3</td><td>–1</td><td>–3</td></tr><tr><td>max</td><td>2</td><td>3</td><td>0</td><td></td></tr></table>Row maximin = –2
Column minimax = 0

Ross's play-safe strategy is Ice
Collwen's play-safe strategy is Gale

Not stable since row maximin ≠ column minimax
OR not stable since row maximin + -col minimax ≠ 0
OR if Ross plays (safe with) Ice then Collwen would be better off playing Ice as well (instead of playing safe with Gale)</td><td>M1

A1

M1

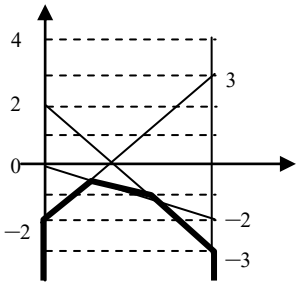
A1

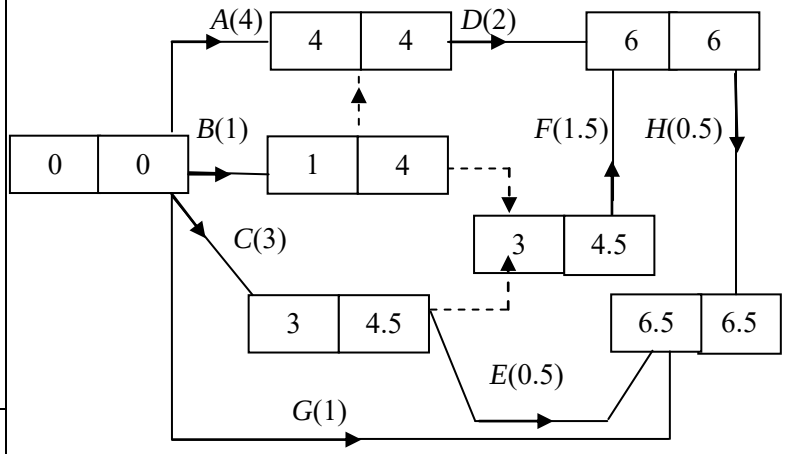
B1

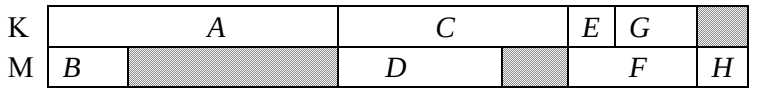
[5]</td><td>May use original tables
Evidence of correct row minima for Ross (–3, –2, –3 or 1, 2, 1) or statement that row maximin = –2 (or equivalent)
Ross's play-safe is Ice

Evidence of column maxima for Collwen (2, 3, 0 or 6, 7, 4) or – col max (–2, –3, 0 or –6, –7, –4 or –2, –1, –4 or 2, 1, 4) but NOT 7, 7, 6 (maxima from Collwen's table) or statement that col minmax = 0 (or equivalent)
Collwen's play-safe is Gale

A valid argument (follow through their working and play-safe choices if possible)
Unstable since –2 ≠ 0 or 2 ≠ 4
Unstable since –2 + 0 ≠ 0 or 2 + 4 ≠ 8</td></tr>
</table>

Question	Answer/Indicative content	Mark	Guidance
(iv)	For Collwen, no dominance between *Fire* and *Ice*: -3 < 3 but 2 > -2 (or 1 > -3) *Fire* and *Gale*: -3 < -2 but 2 > 0 (or 1 > -1) *Ice* and *Gale*: 3 > -2 but -2 < 0 (or -3 < -1) For reference: *F* *I* *G*: 7 1 6 / 2 6 4 / 3 7 5 *F* *I* *G*: –3 3 –2 / 2 –2 0 / 1 –3 –1	B1 B1 B1 **[3]**	Reasoned argument involving identification of strategies and six appropriate (specific) numerical comparisons *F/I*: 7 > 1 but 2 < 6 (or 3 < 7) or negatives of these, or equivalent *F/G*: 7 > 6 but 2 < 4 (or 3 < 5) or equivalent (consistent) *I/G*: 1 < 6 but 6 > 4 (or 7 > 5) or equivalent (consistent) Or (with or without numerical comparisons) *Fire* does not dominate since it is only best when R plays *F* *Ice* does not dominate since it is only best when R plays *I* *Gale* is never best but is never worst either
(v)	(For Ross, *Gale* is) dominated by *Ice* (Ross) always does better by playing *Ice* *F* *I* *G*: *F* –3 3 –2 / *I* 2 –2 0	B1 B1 **[2]**	Condone '*Ice* is better' or equivalent, without explicit reference to 'for each of Collwen's choices', but '*Ice*' on its own is not enough Accept 6 > 5, 2 > 1, 4 > 3 or 2 > 1, –2 > –3 and 0 > –1, or equivalent, without *Ice* named 2 × 3 table showing pay-off's for Ross (cao)
(vi)	 $-2p = 5p - 2$ (or $= 3p - 2(1-p)$) $\Rightarrow p = \frac{2}{7}$	M1 A1 B1 **[3]**	Lines drawn joining (their) 2 to –3, –2 to 3 and 0 to –2 Need 1 unit = whole no sq and at least 5 horizontally Finding the value of *p* corresponding to the maximum height of their lower boundary (value consistent with their graph) 2/7 (cao) without wrong working

Question			Answer/Indicative content	Mark	Guidance
5	(i)		Activity on arc  	B1 B1 B1 B1 **[4]**	Single start with directed arcs labelled *A*, *B*, *C*, *G* coming from it (and no others) and single finish with directed arcs labelled *E*, *G*, *H* going to it (and no others) (without extra dummy arcs) Dealing with precedences for *D* correctly (*D* follows *A* and *B* **but not** *C*; *H* follows *D*) Dealing with precedences for *E* correctly (*E* follows *C* only) Dealing with precedences for *F* correctly (*F* follows *B* and *C* but not *A*; *H* follows *F*) Condone arcs shown undirected, apart from the first mark Condone extra dummies, apart from first mark Need not see weights on arcs
	(ii)		Minimum completion time = 6.5 hours Critical activities are: *A*, *D*, *H*	 M1 M1 A1 B1 B1 **[5]**	Follow through their precedence network if possible for M marks Forward pass substantially correct (≤ 1 independent error) Backward pass substantially correct (≤ 1 independent error) Both passes correct for their precedence network 6.5 (cao) (written, not just from diagram) (units not necessary) *A*, *D*, *H* (cao, not ft)
	(iii)		1.5 hours	B1 **[1]**	Their late time after C minus 3 (units not necessary) Strict follow through from their activity network
	(iv)		If he does *A* first then C cannot finish until 7 hours and *F* cannot finish until 8.5 hours, *H* has still not been done, so the project must take more than 8.5 hours If he does *C* first then *A* cannot finish until 7 hours and *D* cannot finish until 9 hours, so the project must take more than 8.5 hours	 B1 B1 **[2]**	Do not follow through their precedence network here *A* then *C* means *F* cannot finish until 8.5 (or *H* until 9) *C* then *A* means *D* cannot finish until 9 (or H until 9.5), allow '*A* will be delayed but *A* is critical (and 3 + 6.5 > 8.5)'

<table>
<tr><th colspan="3">Question</th><th>Answer/Indicative content</th><th>Mark</th><th>Guidance</th></tr>
<tr><td></td><td>(v)</td><td></td><td>


Schedule presented as a diagram, list or in words</td><td>M1

A1

[2]</td><td>Khalid does A, C, E, G or A, C, G, E and may also do H at the end

All activities completed in 9 hours, with correct durations
B could be alongside A or C; D must come alongside C (after B);
F must be alongside E and G; H must be at the end on its own</td></tr>
<tr><td>6</td><td>(i)</td><td></td><td>
<table>
<tr><th>Stage</th><th>State</th><th>Action</th><th>Working</th><th>Suboptimal maximin</th></tr>
<tr><td>3</td><td>0</td><td>0</td><td>6</td><td>6</td></tr>
<tr><td></td><td>1</td><td>0</td><td>1</td><td>1</td></tr>
<tr><td></td><td>2</td><td>0</td><td>3</td><td>3</td></tr>
<tr><td>2</td><td>0</td><td>0</td><td>min(3, 6) = 3</td><td>3</td></tr>
<tr><td></td><td rowspan="3">1</td><td>0</td><td>min(1, 6) = 1</td><td rowspan="3"></td></tr>
<tr><td></td><td>1</td><td>min(1, 1) = 1</td></tr>
<tr><td></td><td>2</td><td>min(2, 3) = 2</td><td>2</td></tr>
<tr><td></td><td>2</td><td>2</td><td>min(1, 3) = 1</td><td>1</td></tr>
<tr><td>1</td><td>0</td><td>0</td><td>min(3, 3) = 3</td><td rowspan="2">3</td></tr>
<tr><td></td><td></td><td>1</td><td>min(4, 2) = 2</td></tr>
<tr><td></td><td>1</td><td>1</td><td>min(3, 2) = 2</td><td>2</td></tr>
<tr><td></td><td>2</td><td>1</td><td>min(3, 2) = 2</td><td rowspan="2">2</td></tr>
<tr><td></td><td></td><td>2</td><td>min(1, 1) = 1</td></tr>
<tr><td>0</td><td>0</td><td>0</td><td>min(5, 3) = 3</td><td rowspan="3">3</td></tr>
<tr><td></td><td></td><td>1</td><td>min(3, 2) = 2</td></tr>
<tr><td></td><td></td><td>2</td><td>min(4, 2) = 2</td></tr>
</table>
</td><td>B1

M1

A1

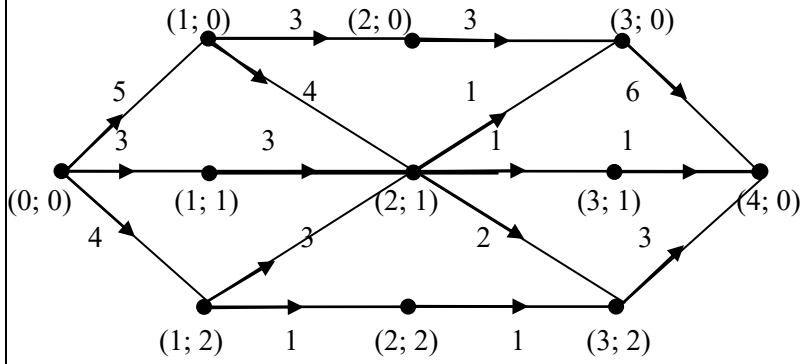
B1

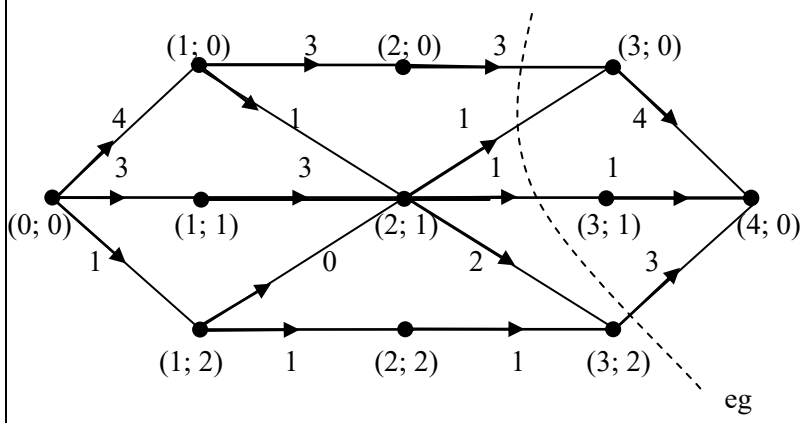
[4]</td><td>Transferring suboptimal values correctly to stage 1

Calculating (their) min values correctly at stage 1

Calculating (their) suboptimal maximin values correctly at stage 1

Stage 0 all correct (cao)</td></tr>
</table>

Question	Answer/Indicative content	Mark	Guidance
(ii)	Maximin value = 3 Route: (0; 0) – (1; 0) – (2; 0) – (3; 0) – (4; 0)	B1 M1 A1 **[3]**	3 (follow through from <u>their</u> table) Their route is correct from <u>their</u> table for stages 1 and 2 Correct route (cao)
(iii)	 **[3]**	 B1 M1 A1 **[3]**	May see working on diagram for previous parts, ignore this Structure and vertex labels all correct (condone arcs not directed) Condone drawn ‘backwards’ Arc weights correct for stages 0 and 3 5, 3, 4 from (0; 0) and 6, 1, 3 into (4; 0) All arc weights correct (must see weights on both arcs through (1;1), (2;0), (2;2) and (3;1))
(iv)	Maximum flow along any route from (0; 0) to (4; 0) and that route <u>Or</u> maximum flow route and its value <u>Or</u> route that maximises flow and value of max flow **[1]**	B1	Any appropriate description involving the idea of ‘flow’ that refers to <u>both</u> value and route of max flow Need flow context, not statements like ‘maximising minimum arc’

Question			Answer/Indicative content	Mark	Guidance
	(v)	(a)	The maximin routes give flow augmenting routes (the weights remaining show the excess capacities)	B1 [1]	Any appropriate description involving the idea of flow augmenting routes or excess capacities or labelling procedure Allow idea of 'augment flows until saturation is reached'
	(v)	(b)		B1 B1 **[2]**	All flows correct (cao) For (1; 1), (2; 0), (2; 2) and (3; 1), may interpret flow from one part correctly labelled and the other left blank Other than this, any blanks will be interpreted as 0 A correct cut (and no incorrect cuts) Cut through saturated arcs to separate (0; 0) from (4; 0) Do not allow any cut that passes through a vertex

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