OCR
RECOGNISING ACHIEVEMENT

GCE

Mathematics

Advanced GCE

Unit **4737:** Decision Mathematics 2

Mark Scheme for June 2013

Oxford Cambridge and RSA Examinations

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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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1. **Annotations**

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
soi	Seen or implied
www	Without wrong working

Subject-specific Marking Instructions for GCE Mathematics (OCR) 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 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.

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

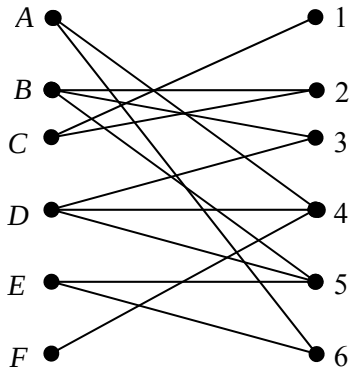
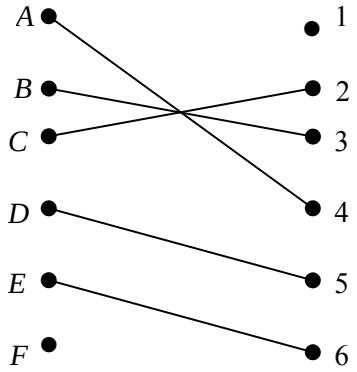
If a candidate attempts a question more than once, and indicates which attempt he/she wishes to be marked, then examiners should do as the candidate requests.

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	Marks	Guidance
1	(i)			M1 A1 **[2]**	Any three students paired to the correct rooms All Correct $A \rightarrow 4, 6$ $D \rightarrow 3, 4, 5$ $B \rightarrow 2, 3, 5$ $E \rightarrow 5, 6$ $C \rightarrow 1, 2$ $F \rightarrow 4$
1	(ii)		Drew has room 5 and Edmund has room 6 Fred is not happy 	B1 B1 **[2]**	Fred or F (cao) Incomplete matching between five pairs (cao)
1	(iii)		$F = 4 - A = 6 - E = 5 - D = 3 - B = 2 - C = 1$ $A = 6$ $B = 2$ $C = 1$ $D = 3$ $E = 5$ $F = 4$	M1 A1 **[2]**	This alternating path written down, starting from F, not implied from matching. Try to follow through their (i) and (ii) if possible This complete matching written down (cao)

<table>
<tr><th colspan="3">Question</th><th>Answer</th><th>Marks</th><th>Guidance</th></tr>
<tr><td>2</td><td>(i)</td><td></td><td>Subtract each entry from a constant (eg 10)</td><td>B1
[1]</td><td>Valid method to convert minimisation to maximisation</td></tr>
<tr><td>2</td><td>(ii)</td><td></td><td>10 – each entry
<table>
<tr><td>0</td><td>4</td><td>0</td><td>2</td><td>5</td><td>5</td></tr>
<tr><td>4</td><td>8</td><td>0</td><td>9</td><td>6</td><td>4</td></tr>
<tr><td>0</td><td>1</td><td>2</td><td>6</td><td>8</td><td>0</td></tr>
<tr><td>1</td><td>6</td><td>1</td><td>5</td><td>5</td><td>2</td><td>(–1)</td></tr>
<tr><td>1</td><td>2</td><td>1</td><td>2</td><td>3</td><td>2</td><td>(–1)</td></tr>
<tr><td>7</td><td>6</td><td>0</td><td>7</td><td>9</td><td>6</td></tr>
</table>
Reduce rows
<table>
<tr><td>0</td><td>4</td><td>0</td><td>2</td><td>5</td><td>5</td></tr>
<tr><td>4</td><td>8</td><td>0</td><td>9</td><td>6</td><td>4</td></tr>
<tr><td>0</td><td>1</td><td>2</td><td>6</td><td>8</td><td>0</td></tr>
<tr><td>0</td><td>5</td><td>0</td><td>4</td><td>4</td><td>1</td></tr>
<tr><td>0</td><td>1</td><td>0</td><td>1</td><td>2</td><td>1</td></tr>
<tr><td>7</td><td>6</td><td>0</td><td>7</td><td>9</td><td>6</td></tr>
<tr><td></td><td>(–1)</td><td></td><td>(–1)</td><td>(–2)</td><td></td></tr>
</table>
Reduce columns
<table>
<tr><td>0</td><td>3</td><td>0</td><td>1</td><td>3</td><td>5</td></tr>
<tr><td>4</td><td>7</td><td>0</td><td>8</td><td>4</td><td>4</td></tr>
<tr><td>0</td><td>0</td><td>2</td><td>5</td><td>6</td><td>0</td></tr>
<tr><td>0</td><td>4</td><td>0</td><td>3</td><td>2</td><td>1</td></tr>
<tr><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>1</td></tr>
<tr><td>7</td><td>5</td><td>0</td><td>6</td><td>7</td><td>6</td></tr>
</table></td><td>B1

M1

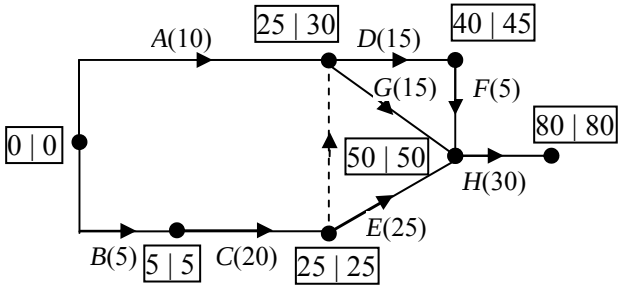
A1

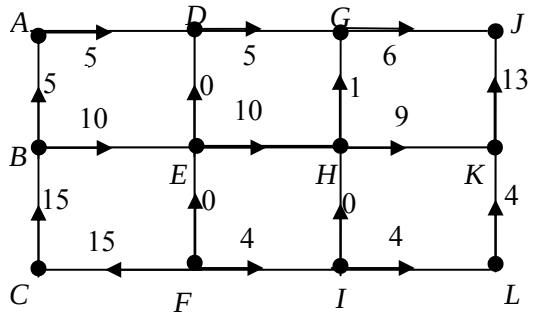
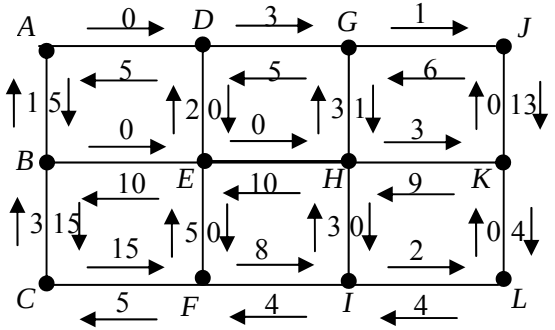
[3]</td><td>Subtracting each entry from a constant (may use some other constant, but require a matrix with no negative values before reducing commences)
Some candidates show working on the table, so entries may be crossed out. Credit work that is legible and consistent.

Correct method for reducing rows (resulting in a correct matrix with a 0 in each row, FT)
(may be implied from a correct matrix)

Correct method for reducing columns, resulting in reduced cost matrix as given in question.
Need evidence of method, not just the correct (given) matrix.</td></tr>
</table>

Question			Answer	Marks	Guidance
2	(iii)		Cross through zeros using four lines 0 3 0 1 3 5 4 7 0 8 4 4 0 0 2 5 6 0 0 4 0 3 2 1 0 0 0 0 0 1 7 5 0 6 7 6	M1	First augmentation started, having crossed through all 0's using at least 4 lines (may be implied from correct augmented matrix)
			Augment by 1 0 2 0 0 2 4 4 6 0 7 3 3 1 0 3 5 6 0 0 3 0 2 1 0 1 0 1 0 0 1 7 4 0 5 6 5	A1	First augmentation correct (or correct for their crossing out)
			Augment by 3 0 2 3 0 2 4 1 3 0 4 0 0 1 0 6 5 6 0 0 3 3 2 1 0 1 0 4 0 0 1 4 1 0 2 3 2	M1	Second augmentation, crossing through 0's using exactly five lines (may be implied from augmented matrix)
				A1	Correct matrix after second augmentation (cao)
			Fred cooks on Tuesday	B1 **[5]**	Follow through their final matrix (do not need to give allocation)
2	(iv)		B = Thurs; C = Mon; D = Fri; E = Weds A = Sun; F = Tues	M1 A1 **[2]**	A valid matching for B, C, D and E, from their final matrix (ignoring what candidate says about Alice and Fred) This matching (cao), including A and F

Question			Answer	Marks	Guidance
3	(i) (ii)			M1 A1 **[2]**	Correct structure, even with unnecessary dummies and no directions, arcs must be labelled *A*, *B*, *C*, … Correct structure with no unnecessary dummies, directed arcs and arcs labelled *A*, *B*, *C*, …
				   M1 M1 A1 **[3]**	Follow through their network if possible Forward pass with at most 1 independent error Backward pass with at most 1 independent error Both passes correct for their (non trivial) network and correct durations
3	(iii)		Minimum project completion time = 80 mins Critical activities: *B*, *C*, *E*, *H*	B1 B1 **[2]**	80 minutes (cao), condone omission of units *B*, *C*, *E*, *H* (cao)
3	(iv)		Eg *B* *A* *A* *D* *D* *D* *F* *H* *H* *H* *H* *H* *H* *C* *C* *C* *G* *G* *G* *E* *E* *E* *E* *E*	M1 A1 **[2]**	Molly does *B*, *A*, *F*, *H* with *B* first All activities accounted for, precedences correct and duration = 80
3	(v)		*B* *A* *A* *E* *E* *E* *E* *E* *F* *H* *H* *H* *H* *H* *H* *C* *C* *C* *C* *D* *D* *D* *G* *G* *G*	M1 A1 **[2]**	Molly does *B*, *A*, *E*, *F*, *H* with *B* first All activities accounted for, precedences correct and duration = 85

Question			Answer	Marks	Guidance
4	(i)		*F* only has flow out, no flow in Sink is at *J*	B1 B1 **[2]**	All arrows at *F* point out *J*
4	(ii)		30 litres per second	B1 **[1]**	30 (cao), condone units missing
4	(iii)		At most 5 flows out (of *BA*) along *AD* *BA* ≤ 5 and *BE* ≤ 10, so *CB* ≤ 15 But any flow in *FC* must go along *CB*, hence *FC* ≤ 15 (as given in question)	B1 M1 A1 **[3]**	Condone *AD* = 5, as possibly referring to capacity Allow 'only 5 can flow out' (capacity) but not '5 (does) flow out' Using *BA* and *BE* to get *CB* (limit) 15 (or 'through *B*') Correct argument for *FC*, using ≤ (or in words)
4	(iv)			M1 A1 **[2]**	A flow from *F* to *J* in which *DE* = *FE* = *IH* = 0 and *KJ* = 13 (even if some capacities are not met) This flow (cao)
4	(v)		 *F* – *E* – *D* – *G* – *J* or *F* – *I* – *H* – *G* – *J* (flow = 1) Cut {*A*, *B*, *C*, *D*, *E*, *F*, *G*, *H*, *I*, *K*, *L*}, {*J*} Max flow = 20 litres per sec	M1 A1 B1 B1 B1 **[5]**	At least six arcs with arrows correctly labelled (or all reversed) Correct (or all reversed) If augmenting is done on diagram accept original values provided they can be read *F* – *E* – *D* – *G* – *J* or *F* – *I* – *H* – *G* – *J* (or in reverse) (ft labelling) Cut through arcs *GJ* and *KJ* written or unambiguously shown (cao) 20 (cao)

<table>
<tr><th colspan="3">Question</th><th>Answer</th><th>Marks</th><th>Guidance</th></tr>
<tr><td>5</td><td>(i)</td><td></td><td>Maximin is the route for which the minimum arc weight on that route is largest</td><td>B1

[1]</td><td>Correct explanation of maximin</td></tr>
<tr><td>5</td><td>(ii)</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 rowspan="3">3</td><td>0</td><td>0</td><td>20</td><td>20</td></tr>
<tr><td>1</td><td>0</td><td>18</td><td>18</td></tr>
<tr><td>2</td><td>0</td><td>24</td><td>24</td></tr>
<tr><td rowspan="5">2</td><td rowspan="2">0</td><td>0</td><td>min(12, 20) = 12</td><td rowspan="2">17</td></tr>
<tr><td>1</td><td>min(17, 18) = 17</td></tr>
<tr><td rowspan="2">1</td><td>0</td><td>min(16, 20) = 16</td><td rowspan="2">16</td></tr>
<tr><td>2</td><td>min(14, 24) = 14</td></tr>
<tr><td rowspan="2">2</td><td>1</td><td>min(13, 18) = 13</td><td rowspan="2">13</td></tr>
<tr><td>2</td><td>min(11, 24) = 11</td></tr>
<tr><td rowspan="6">1</td><td rowspan="3">0</td><td>0</td><td>min(18, 17) = 17</td><td rowspan="3">17</td></tr>
<tr><td>1</td><td>min(16, 16) = 16</td></tr>
<tr><td>2</td><td>min(14, 13) = 13</td></tr>
<tr><td rowspan="2">1</td><td>0</td><td>min(17, 17) = 17</td><td rowspan="2">17</td></tr>
<tr><td>2</td><td>min(15, 13) = 13</td></tr>
<tr><td rowspan="2">2</td><td>1</td><td>min(13, 16) = 13</td><td rowspan="2">13</td></tr>
<tr><td>2</td><td>min(15, 13) = 13</td></tr>
<tr><td rowspan="3">0</td><td rowspan="3">0</td><td>0</td><td>min(20, 17) = 17</td><td rowspan="3">17</td></tr>
<tr><td>1</td><td>min(22, 17) = 17</td></tr>
<tr><td>2</td><td>min(26, 13) = 13</td></tr>
</table>
Load = 17 tonnes
(0; 0) – (1; 0) – (2; 0) – (3; 1) – (4; 0)
(0; 0) – (1; 1) – (2; 0) – (3;1) – (4; 0)</td><td>M1
A1
B1

M1
A1

M1
A1

M1
A1

B1
B1
B1

[12]</td><td>Stage and state columns correct
Action column correct
At least one further column for working or values

Correct method for working seen or implied for stage 2
Suboptimal values correct for stage 2 (cao)

Correct method for working seen or implied for stage 1
Suboptimal values correct for stage 1 (cao)

Correct method for working seen or implied for stage 0
Stage 0 correct (cao)

17 (condone units missing) stated, not just implied from table
One correct route (cao) (allow route reversed)
Second correct route (cao) (allow route reversed)
with no other routes given</td></tr>
<tr><td>5</td><td>(iii)</td><td></td><td>18 tonnes using (0; 0)–(1; 0)–(2; 0)–(3; 1)–(4; 0)

18 is the largest arc weight from any state in stage 1 to stage 2

Increasing capacity of (2;0) to (3; 1) cannot increase flow to more than 18 because (3; 1) to (4; 0) has capacity 18</td><td>B1

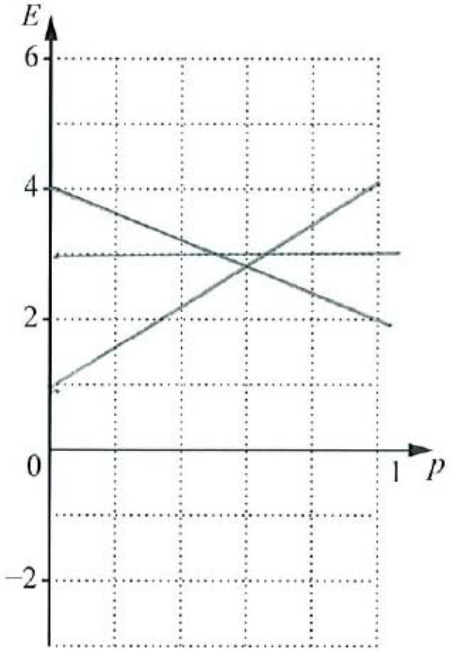
B1

[2]</td><td>18 (condone units missing), route not needed

Explaining why no more than 18 is possible

(1; 1) to (2; 0) can only carry 17 so (1; 0) to (2; 0) must be used and this can carry at most 18 and hence 18 is the maximum</td></tr>
</table>

Question			Answer	Marks	Guidance
6	(i)		3	B1 **[1]**	
6	(ii)		<table><tr><th></th><th>Jeff</th><th>Kathy</th><th>Leo</th></tr><tr><td>Greg</td><td>–1</td><td>1</td><td>3</td></tr><tr><td>Hakkim</td><td>3</td><td>1</td><td>–3</td></tr><tr><td>Iona</td><td>–3</td><td>–5</td><td>1</td></tr></table>	B1 **[1]**	Matrix converted as described (cao)
6	(iii)		<table><tr><th></th><th>Jeff</th><th>Kathy</th><th>Leo</th><th>row min</th></tr><tr><td>Greg</td><td>–1</td><td>1</td><td>3</td><td>–1</td></tr><tr><td>Hakkim</td><td>3</td><td>1</td><td>–3</td><td>–3</td></tr><tr><td>Iona</td><td>–3</td><td>–5</td><td>1</td><td>–5</td></tr><tr><td>col max</td><td>3</td><td>1</td><td>3</td><td></td></tr></table> Play-safe for Royal team is Greg Play-safe for Carlton team is Kathy Not stable since $-1 \neq 1$ If Royal team play safe, Carlton team should choose Jeff	M1 M1 A1 B1 B1 **[5]**	Row minima calculated for their zero-sum table $\pm$ column maxima calculated for their zero-sum table Play-safes G and K (cao) Or equivalent, or in words (FT their table/working) J (cao)
6	(iv)		Row for Iona is dominated by row for Greg since no matter which player the Carlton team choose Iona never expects to win as many legs as Greg	B1 **[1]**	$-3 < -1$, $-5 < 1$ and $1 < 3$ (or $1 < 2$, $0 < 3$ and $3 < 4$) or equivalent (not enough to just say 'dominated by *G*', need three correct comparisons or a fully correct description)
6	(v)		Using the original table, reduced <table><tr><th></th><th>Jeff</th><th>Kathy</th><th>Leo</th><th>prob</th></tr><tr><td>Greg</td><td>2</td><td>3</td><td>4</td><td>p</td></tr><tr><td>Hakkim</td><td>4</td><td>3</td><td>1</td><td>$1 - p$</td></tr></table> Jeff: $2p + 4(1 - p) = 4 - 2p$, as given Kathy: $3p + 3(1 - p) = 3$ Leo: $4p + (1 - p) = 1 + 3p$	 B1 M1 A1 **[3]**	Or use zero-sum table to get Jeff: $-p + 3(1 - p) = 3 - 4p$ Then add 5 and divide by 2 to get $4 - 2p$ Showing how $4 - 2p$ was achieved Correct method for K or L, using original table or zero-sum table ($K = 1$, $L = 6p - 3$) Both $K = 3$ and $L = 1 + 3p$

Question			Answer	Marks	Guidance
6	(vi)			M1 A1	Line E = 4 – 2*p* correct (using printed scales) All three lines correct, from their part **(v)**
			Optimal *p* when $4 - 2p = 1 + 3p \Rightarrow p = 0.6$ Expect to win 2.8 legs	B1 B1 **[4]**	0.6 (cao) 2.8 (cao)
6	(vii)		eg One team could win 3 3 3 3 0 0 0 legs then they have won 4 rounds but only 12 legs and other team has won 3 rounds and 23 legs (or 17 legs using 'best of five')	B1 **[1]**	An example in which one team wins at least 4 rounds <u>and</u> at most 17 legs (sum of legs = 35 if each round has five legs) May give an example using specific pairs of players and expected wins. We need to be able to see the number of rounds and legs won for one team and be able to see that the solution works, from what is written.

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