

Mark Scheme for June 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

Annotation	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 Marking Instructions

- 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.

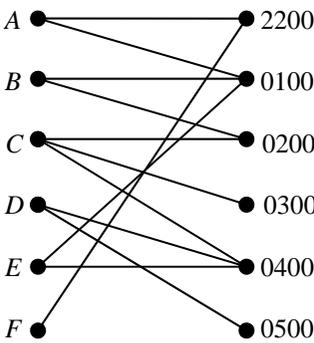
If there are two or more attempts at a question which have not been crossed out, examiners should mark what appears to be the last (complete) attempt and ignore the others.

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.

Please mark work that is in the wrong answer space provided it is obvious which part of which question the candidate is attempting.

Question		Answer	Marks	Guidance
1	(i)		<p>B1</p> <p>[1]</p>	<p>Correct bipartite graph</p>
1	(ii)	<p>$0500 = D - 0400 = E$</p> <p>$A = 2200 \quad B = 0100 \quad C = 0200$ $D = 0500 \quad E = 0400$</p>	<p>M1</p> <p>A1</p> <p>[2]</p>	<p>This alternating path written down, starting at 0500, not implied from matching (Do not allow paths from (ii) and (iii) swapped) This matching for A, B, C, D and E written down</p>
1	(iii)	<p>$F = 2200 - A = 0100 - B = 0200 - C = 0300$</p> <p>$A = 0100 \quad B = 0200 \quad C = 0300$ $D = 0500 \quad E = 0400 \quad F = 2200$</p>	<p>M1</p> <p>A1</p> <p>[2]</p>	<p>This alternating path written down, starting from F, not implied from matching (Do not allow paths from (ii) and (iii) swapped) This complete matching written down</p>

Question	Answer	Marks	Guidance																																																																											
2 (i)	Subtract each entry from a constant (eg 10) or (each entry - 10) and then $\times -1$	B1 [1]	Valid method to convert minimisation to maximisation Not: 'subtract the biggest number' or 'subtract by the biggest number'																																																																											
(ii)	<p>10 - each entry</p> <table border="1" data-bbox="448 414 985 590"> <tr><td>2</td><td>10</td><td>3</td><td>9</td><td>9</td></tr> <tr><td>1</td><td>8</td><td>3</td><td>10</td><td>8</td></tr> <tr><td>0</td><td>6</td><td>1</td><td>7</td><td>5</td></tr> <tr><td>3</td><td>8</td><td>4</td><td>9</td><td>8</td></tr> <tr><td>0</td><td>2</td><td>1</td><td>4</td><td>3</td></tr> </table> <p>Reduce rows</p> <table border="1" data-bbox="448 694 985 869"> <tr><td>0</td><td>8</td><td>1</td><td>7</td><td>7</td></tr> <tr><td>0</td><td>7</td><td>2</td><td>9</td><td>7</td></tr> <tr><td>0</td><td>6</td><td>1</td><td>7</td><td>5</td></tr> <tr><td>0</td><td>5</td><td>1</td><td>6</td><td>5</td></tr> <tr><td>0</td><td>2</td><td>1</td><td>4</td><td>3</td></tr> </table> <p>Reduce columns</p> <table border="1" data-bbox="448 973 985 1149"> <tr><td>0</td><td>6</td><td>0</td><td>3</td><td>4</td></tr> <tr><td>0</td><td>5</td><td>1</td><td>5</td><td>4</td></tr> <tr><td>0</td><td>4</td><td>0</td><td>3</td><td>2</td></tr> <tr><td>0</td><td>3</td><td>0</td><td>2</td><td>2</td></tr> <tr><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td></tr> </table>	2	10	3	9	9	1	8	3	10	8	0	6	1	7	5	3	8	4	9	8	0	2	1	4	3	0	8	1	7	7	0	7	2	9	7	0	6	1	7	5	0	5	1	6	5	0	2	1	4	3	0	6	0	3	4	0	5	1	5	4	0	4	0	3	2	0	3	0	2	2	0	0	0	0	0	M1 A1 B1 [3]	(May use some other constant) Correct method for reducing rows (condone 1 arithmetic error provided there is a 0 in each row) Correct matrix after reducing rows (cao) Correct method for reducing columns, with some evidence that columns are being reduced, resulting in the reduced cost matrix as given in question
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Question	Answer	Marks	Guidance																																																		
2	<p data-bbox="219 217 275 240">(iii)</p> <p data-bbox="371 217 808 240">Cross through zeros using three lines</p> <table border="1" data-bbox="450 280 987 456"> <tr><td>0</td><td>6</td><td>0</td><td>3</td><td>4</td></tr> <tr><td>0</td><td>5</td><td>1</td><td>5</td><td>4</td></tr> <tr><td>0</td><td>4</td><td>0</td><td>3</td><td>2</td></tr> <tr><td>0</td><td>3</td><td>0</td><td>2</td><td>2</td></tr> <tr><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td></tr> </table> <p data-bbox="371 563 539 587">Augment by 2</p> <table border="1" data-bbox="450 627 987 802"> <tr><td>0</td><td>4</td><td>0</td><td>1</td><td>2</td></tr> <tr><td>0</td><td>3</td><td>1</td><td>3</td><td>2</td></tr> <tr><td>0</td><td>2</td><td>0</td><td>1</td><td>0</td></tr> <tr><td>0</td><td>1</td><td>0</td><td>0</td><td>0</td></tr> <tr><td>2</td><td>0</td><td>2</td><td>0</td><td>0</td></tr> </table> <p data-bbox="371 874 943 1007">Order in which they attempt to get into building: Hilary, Ken, Gary, Jenni, Ieuan $H = 9, K = 8, G = 7, J = 1, I = 5$ Jenni is least likely to succeed</p>	0	6	0	3	4	0	5	1	5	4	0	4	0	3	2	0	3	0	2	2	0	0	0	0	0	0	4	0	1	2	0	3	1	3	2	0	2	0	1	0	0	1	0	0	0	2	0	2	0	0	<p data-bbox="1128 320 1167 344">M1</p> <p data-bbox="1128 735 1167 759">A1</p> <p data-bbox="1128 911 1167 935">B1</p> <p data-bbox="1128 975 1167 999">B1</p> <p data-bbox="1128 1015 1167 1038">[4]</p>	<p data-bbox="1234 320 2029 416">Crossing through zeros correctly and substantially correct attempt at augmenting by 2 in a single step (may be implied from augmented matrix)</p> <p data-bbox="1234 735 2018 799">Correct matrix after augmenting, and no further attempts to reduce or augment</p> <p data-bbox="1234 911 1379 935"><i>H, K, G, J, I</i></p> <p data-bbox="1234 975 1379 999"><i>J</i> (cao www)</p>
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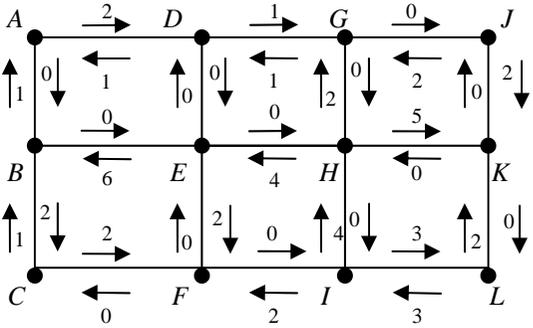
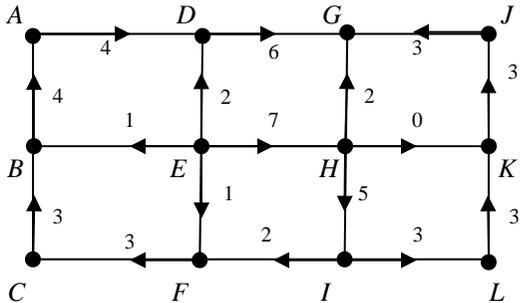
Question	Answer	Marks	Guidance																																																														
3	<table border="1"> <thead> <tr> <th data-bbox="421 245 517 316">Stage</th> <th data-bbox="517 245 613 316">State</th> <th data-bbox="613 245 725 316">Action</th> <th data-bbox="725 245 853 316">Working</th> <th data-bbox="853 245 1010 316">Suboptimal latest time</th> </tr> </thead> <tbody> <tr> <td data-bbox="421 316 517 395" rowspan="2">3</td> <td data-bbox="517 316 613 354">0</td> <td data-bbox="613 316 725 354">0</td> <td data-bbox="725 316 853 354">15 - 4</td> <td data-bbox="853 316 1010 354">*11 am</td> </tr> <tr> <td data-bbox="517 354 613 395">1</td> <td data-bbox="613 354 725 395">0</td> <td data-bbox="725 354 853 395">15 - 2</td> <td data-bbox="853 354 1010 395">* 1 pm</td> </tr> <tr> <td data-bbox="421 395 517 549" rowspan="3">2</td> <td data-bbox="517 395 613 434">0</td> <td data-bbox="613 395 725 434">0</td> <td data-bbox="725 395 853 434">11 - 4</td> <td data-bbox="853 395 1010 434">* 7 am</td> </tr> <tr> <td data-bbox="517 434 613 513" rowspan="2">1</td> <td data-bbox="613 434 725 472">0</td> <td data-bbox="725 434 853 472">11 - 3</td> <td data-bbox="853 434 1010 513" rowspan="2">*10 am</td> </tr> <tr> <td data-bbox="613 472 725 513">1</td> <td data-bbox="725 472 853 513">13 - 3</td> </tr> <tr> <td data-bbox="517 513 613 549">2</td> <td data-bbox="613 513 725 549">1</td> <td data-bbox="725 513 853 549">13 - 4</td> <td data-bbox="853 513 1010 549">* 9 am</td> </tr> <tr> <td data-bbox="421 549 517 849" rowspan="7">1</td> <td data-bbox="517 549 613 657" rowspan="3">0</td> <td data-bbox="613 549 725 587">0</td> <td data-bbox="725 549 853 587">7 - 2</td> <td data-bbox="853 549 1010 657" rowspan="3">* 7 am</td> </tr> <tr> <td data-bbox="613 587 725 625">1</td> <td data-bbox="725 587 853 625">10 - 3</td> </tr> <tr> <td data-bbox="613 625 725 657">2</td> <td data-bbox="725 625 853 657">9 - 3</td> </tr> <tr> <td data-bbox="517 657 613 772" rowspan="3">1</td> <td data-bbox="613 657 725 695">0</td> <td data-bbox="725 657 853 695">7 - 2</td> <td data-bbox="853 657 1010 695">* 5 am</td> </tr> <tr> <td data-bbox="613 695 725 734">1</td> <td data-bbox="725 695 853 734">10 - 6</td> <td data-bbox="853 695 1010 772" rowspan="2">*</td> </tr> <tr> <td data-bbox="613 734 725 772">2</td> <td data-bbox="725 734 853 772">9 - 4</td> </tr> <tr> <td data-bbox="517 772 613 849" rowspan="2">2</td> <td data-bbox="613 772 725 810">1</td> <td data-bbox="725 772 853 810">10 - 2</td> <td data-bbox="853 772 1010 849" rowspan="2">* 8 am</td> </tr> <tr> <td data-bbox="613 810 725 849">2</td> <td data-bbox="725 810 853 849">9 - 3</td> </tr> <tr> <td data-bbox="421 849 517 963" rowspan="3">0</td> <td data-bbox="517 849 613 963" rowspan="3">0</td> <td data-bbox="613 849 725 887">0</td> <td data-bbox="725 849 853 887">7 - 5</td> <td data-bbox="853 849 1010 963" rowspan="3">* 2 am</td> </tr> <tr> <td data-bbox="613 887 725 925">1</td> <td data-bbox="725 887 853 925">5 - 4</td> </tr> <tr> <td data-bbox="613 925 725 963">2</td> <td data-bbox="725 925 853 963">8 - 7</td> </tr> </tbody> </table>	Stage	State	Action	Working	Suboptimal latest time	3	0	0	15 - 4	*11 am	1	0	15 - 2	* 1 pm	2	0	0	11 - 4	* 7 am	1	0	11 - 3	*10 am	1	13 - 3	2	1	13 - 4	* 9 am	1	0	0	7 - 2	* 7 am	1	10 - 3	2	9 - 3	1	0	7 - 2	* 5 am	1	10 - 6	*	2	9 - 4	2	1	10 - 2	* 8 am	2	9 - 3	0	0	0	7 - 5	* 2 am	1	5 - 4	2	8 - 7	<p>M1 A1</p> <p>M1 A1</p> <p>M1 A1</p>	<p>Stage and state columns correct Action column correct</p> <p>Correct method for working seen or implied for stage 2 (structure must be correct) Suboptimal values correct for stage 2 (cao)</p> <p>Correct method for working seen or implied for stage 1 (structure must be correct) Stage 1 correct (cao)</p>
Stage	State	Action	Working	Suboptimal latest time																																																													
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	<p>Alternatively using shortest path and then converting to times at the end</p> <table border="1" data-bbox="421 312 1008 973"> <thead> <tr> <th>Stage</th> <th>State</th> <th>Action</th> <th>Working</th> <th>Suboptimal minimum</th> </tr> </thead> <tbody> <tr> <td rowspan="2">3</td> <td>0</td> <td>0</td> <td>4</td> <td>* 4</td> </tr> <tr> <td>1</td> <td>0</td> <td>2</td> <td>* 2</td> </tr> <tr> <td rowspan="3">2</td> <td>0</td> <td>0</td> <td>4 + 4</td> <td>* 8</td> </tr> <tr> <td rowspan="2">1</td> <td>0</td> <td>3 + 4</td> <td></td> </tr> <tr> <td>1</td> <td>3 + 2</td> <td>* 5</td> </tr> <tr> <td>2</td> <td>1</td> <td>4 + 2</td> <td>* 6</td> </tr> <tr> <td rowspan="8">1</td> <td rowspan="3">0</td> <td>0</td> <td>2 + 8</td> <td></td> </tr> <tr> <td>1</td> <td>3 + 5</td> <td>* 8</td> </tr> <tr> <td>2</td> <td>3 + 6</td> <td></td> </tr> <tr> <td rowspan="3">1</td> <td>0</td> <td>2 + 8</td> <td>* 10</td> </tr> <tr> <td>1</td> <td>6 + 5</td> <td></td> </tr> <tr> <td>2</td> <td>4 + 6</td> <td>*</td> </tr> <tr> <td rowspan="2">2</td> <td>1</td> <td>2 + 5</td> <td>* 7</td> </tr> <tr> <td>2</td> <td>3 + 6</td> <td></td> </tr> <tr> <td rowspan="3">0</td> <td rowspan="3">0</td> <td>0</td> <td>5 + 8</td> <td>* 13</td> </tr> <tr> <td>1</td> <td>4 + 10</td> <td></td> </tr> <tr> <td>2</td> <td>7 + 7</td> <td></td> </tr> </tbody> </table> <p>Latest take-off time = 2 am</p> <p>(0; 0) – (1; 0) – (2; 1) – (3; 1) – (4; 0)</p> <p style="margin-left: 40px;"> <i>A</i> <i>E</i> <i>H</i> 7 am 10 am 1 pm </p>	Stage	State	Action	Working	Suboptimal minimum	3	0	0	4	* 4	1	0	2	* 2	2	0	0	4 + 4	* 8	1	0	3 + 4		1	3 + 2	* 5	2	1	4 + 2	* 6	1	0	0	2 + 8		1	3 + 5	* 8	2	3 + 6		1	0	2 + 8	* 10	1	6 + 5		2	4 + 6	*	2	1	2 + 5	* 7	2	3 + 6		0	0	0	5 + 8	* 13	1	4 + 10		2	7 + 7		<p>B1</p> <p>M1</p> <p>A1</p> <p>[9]</p>	<p>2 am (cao) as a clock time (allow 24 hour clock times but not just 2)</p> <p><i>A</i>, <i>E</i> and <i>H</i> (cao) as letters, not (stage; state)</p> <p>7 am, 10 am, 1 pm (cao), as clock times</p>
Stage	State	Action	Working	Suboptimal minimum																																																																				
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		1	4 + 10																																																																					
		2	7 + 7																																																																					

Question		Answer	Marks	Guidance																									
4	(i)	<table border="1" style="margin-left: auto; margin-right: auto;"> <thead> <tr> <th></th> <th>Chris</th> <th>Jamie</th> <th>Wendy</th> <th>row min</th> </tr> </thead> <tbody> <tr> <th>Andy</th> <td>-3</td> <td>2</td> <td>-4</td> <td>-4</td> </tr> <tr> <th>Kath</th> <td>5</td> <td>4</td> <td>-6</td> <td>-6</td> </tr> <tr> <th>Zac</th> <td>1</td> <td>-4</td> <td>-5</td> <td>-5</td> </tr> <tr> <th>col max</th> <td>5</td> <td>4</td> <td>-4</td> <td></td> </tr> </tbody> </table> <p>Play-safe for rowers is Andy Play-safe for cyclists is Wendy</p> <p>$\max(\text{row min}) = -4 = \min(\text{col max}) \Rightarrow \text{stable}$ row maximin = col minimax</p>		Chris	Jamie	Wendy	row min	Andy	-3	2	-4	-4	Kath	5	4	-6	-6	Zac	1	-4	-5	-5	col max	5	4	-4		<p>M1</p> <p>A1</p> <p>M1</p> <p>A1</p> <p>B1</p> <p>[5]</p>	<p>Showing row min values -4, -6, -5; if values are not shown condone talking about maximin or 'highest lowest'</p> <p>Naming Andy or A as play-safe (not just identifying row) SC: Naming Andy or A without working or identifying A row www \Rightarrow B1</p> <p>Showing col max values 5, 4, -4 (or -5, -4, 4) or stating that W dominates over C and J; if values are not shown condone talking about minimax or 'lowest highest', or equivalent</p> <p>Naming Wendy or W as play-safe (not just identifying column) SC: Naming Wendy or W without working or identifying W column www \Rightarrow B1</p> <p>Showing that game is stable, or in words (if Wendy plays then A is best choice for rowers and if Andy plays then W is best choice for cyclists)</p>
	Chris	Jamie	Wendy	row min																									
Andy	-3	2	-4	-4																									
Kath	5	4	-6	-6																									
Zac	1	-4	-5	-5																									
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	Chris	Jamie	row min																										
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col max	1	2																											

Question		Answer	Marks	Guidance
4	(iii)	$A = 0.5 \times (-3) + 0.5 \times (2) = -0.5$ $Z = -1.5$	B1 B1 [2]	-0.5 (cao) -1.5 (cao)
4	(iv)	Know it must be a mixed strategy, $p \neq 0$ or 1 $A = 3p - 2(1 - p)$ or $5p - 2$ $Z = -1p + 4(1 - p)$ or $4 - 5p$ $5p - 2 = 4 - 5p$ $\Rightarrow p = 0.6$	B1 M1 A1 [3]	Both expressions in any form Solving where their expressions are equal 0.6 (cao) from a valid method
4	(v)	$-3q + (1 - q) = 2q - 4(1 - q)$ (or either of these = -1) $\Rightarrow 1 - 4q = 6q - 4$ $\Rightarrow q = 0.5$	B1 M1 A1 [3]	Either expression in any form Solving where their expressions are equal (or where either of them equals $-E$ from part (iv)) 0.5 (cao) from a valid method

Question	Answer	Marks	Guidance
5 (i)	Source is E G only has flow into it, no flow out	B1 B1 [2]	E All arrows at G point in
5 (ii)	$6 + 7 - 2$ $= 11$ litres per second	M1 A1 [2]	Answer given as 9, 11 or 13 www 11 (cao), condone units missing
5 (iii)	At most 3 flows into JG along KJ $HK = 0$ $IL = 3$	B1 B1 B1 [3]	Upper capacity $KJ = 3$; condone $KJ = 3$, 'max 3 flows in', 'only 3 can enter J ' but not 'only 3 enters J ' without reference to K 0 (cao) 3 (cao)
5 (iv)	At least 2 flows along IF and 3 flows along IL (to LK) $EH = 7$ $CB = 3$	M1 A1 B1 B1 [4]	2 must flow in IF (condone: '2 out to F '; 'min IF ') and $IL = 3$ (condone: '3 to L '; 'min LK ') (or M1 and A1 swapped) 7 (cao) 3 (cao)
5 (v)		M1 A1 [2]	A flow from E to G of 10 in which $JG = 3$ and $HI = 5$ (even if some capacities are not met) This flow (cao) (Interpret blanks as 0)

Question	Answer	Marks	Guidance
<p>5 (vi)</p>		<p>M1 A1 [2]</p>	<p>At least six arcs with arrows correctly labelled (or all reversed) cao (or all reversed)</p>
<p>5 (vii)</p>	<p>$E - B - A - D - G$</p>  <p>11 is max flow since cut in (ii) = 11</p>	<p>B1 B1 B1 [3]</p>	<p>This path (or in reverse) This flow of 11 litres per second (cao) (Interpret blanks as 0) Referring to cut in (ii) or convincing reasoning</p>

Question	Answer	Marks	Guidance
6 (i)		<p>M1</p> <p>A1</p> <p>[2]</p>	<p>Correct structure, even with unnecessary dummies and no directions, arcs must be labelled <i>A, B, C, ...</i> Single start and single finish</p> <p>Correct structure with no unnecessary dummies, directed arcs and arcs labelled <i>A, B, C, ...</i></p>
6 (ii)	<p>Minimum project completion time = 12 hours Critical activities: <i>B, C, D, I</i></p>	<p>M1</p> <p>M1</p> <p>A1</p> <p>B1</p> <p>B1</p> <p>[5]</p>	<p>Forward pass correct (ft their network if possible) Backward pass correct (ft their network if poss) Both passes correct (condone unnecessary dummies or implied directions, but not wrong structure)</p> <p>12 hours (cao), condone omission of units <i>B, C, D, I</i> (cao)</p>
6 (iii)	<p>For <i>D</i> to happen, <i>A, B</i> and <i>C</i> must be complete Sally cannot do any of these activities on her own If they share <i>A</i> and <i>B</i> this takes $1 + 2 = 3$ hours Sally cannot help with <i>C</i> so this takes another 2 hours</p>	<p>M1</p> <p>A1</p> <p>[2]</p>	<p><i>A</i> and <i>B</i> need (at least) 3 hours, can share <i>A</i> and <i>B</i></p> <p><i>C</i> takes 2 hours, <i>C</i> cannot be shared</p>

Question		Answer	Marks	Guidance																																																		
6	(iv)	<p>Sally does <i>F, G</i> and $I = 9$ hours and shares <i>A, B, D</i> and $E = 9$ hours</p> <p>Tariq will take 9 hours for the shared activities and another 6 hours for <i>C, H</i> and <i>J</i> So he takes 15 hours</p>	<p>B1 B1</p> <p>B1 [3]</p>	<p>$F, G, I = 9$ Sharing <i>A, B, D, E = 9</i> (total time 18 hours given in question) SC: ‘does <i>F, G, I</i> and shares <i>A, B, D, E = 18</i>’ (with no durations) ⇒ B1</p> <p>15 (cao), condone omission of units</p>																																																		
6	(v)	<p>Cannot do any of <i>D, E, G</i> until <i>A, B</i> and <i>C</i> are done This is (at least) 5 hours from the start <i>F, G</i> and $I = 9$ hours, <i>D</i> and $E = 6$ hours $5 + 6 + 9 = 20$ hours</p>	<p>M1</p> <p>A1 [2]</p>	<p>Has to wait for Tariq to do <i>C</i></p> <p>2 hour delay giving $18 + 2 = 20$ hours 20 (cao), condone omission of units</p>																																																		
6	(vi)	<p>e.g. Share <i>AB</i>, T does <i>C</i>, share <i>DEFG</i>, T does <i>HJ</i>, S does <i>I</i></p> <p>e.g.</p> <table border="1" style="margin-left: 20px;"> <tr> <td><i>ABC</i></td> <td><i>ABC</i></td> <td><i>ABC</i></td> <td><i>ABC</i></td> <td><i>ABC</i></td> </tr> <tr> <td>5 hrs</td> <td>5 hrs</td> <td>5 hrs</td> <td>5 hrs</td> <td>5 hrs</td> </tr> <tr> <td>share</td> <td><i>DEFG</i></td> <td><i>DE</i></td> <td><i>DE</i></td> <td><i>DF</i></td> </tr> <tr> <td>Tariq</td> <td><i>HJ</i></td> <td><i>FHJ</i></td> <td><i>GHJ</i></td> <td><i>EHJ</i></td> </tr> <tr> <td>Sally</td> <td><i>I</i></td> <td><i>GI</i></td> <td><i>FI</i></td> <td><i>GI</i></td> </tr> </table> <table border="1" style="margin-left: 20px;"> <tr> <td><i>ABC</i></td> <td><i>ABC</i></td> <td><i>ABC</i></td> <td><i>ABC</i></td> <td><i>ABC</i></td> </tr> <tr> <td>5 hrs</td> <td>5 hrs</td> <td>5 or 6</td> <td>5 or 6</td> <td>5, 6, 7</td> </tr> <tr> <td>share</td> <td><i>EF</i></td> <td><i>G</i></td> <td><i>DG</i></td> <td><i>D</i></td> </tr> <tr> <td>Tariq</td> <td><i>DHJ</i></td> <td><i>DEHJ</i></td> <td><i>EHJ</i></td> <td><i>DEHJ</i></td> </tr> <tr> <td>Sally</td> <td><i>GI</i></td> <td><i>FI</i></td> <td><i>FI</i></td> <td><i>FGI</i></td> </tr> </table>	<i>ABC</i>	<i>ABC</i>	<i>ABC</i>	<i>ABC</i>	<i>ABC</i>	5 hrs	share	<i>DEFG</i>	<i>DE</i>	<i>DE</i>	<i>DF</i>	Tariq	<i>HJ</i>	<i>FHJ</i>	<i>GHJ</i>	<i>EHJ</i>	Sally	<i>I</i>	<i>GI</i>	<i>FI</i>	<i>GI</i>	<i>ABC</i>	<i>ABC</i>	<i>ABC</i>	<i>ABC</i>	<i>ABC</i>	5 hrs	5 hrs	5 or 6	5 or 6	5, 6, 7	share	<i>EF</i>	<i>G</i>	<i>DG</i>	<i>D</i>	Tariq	<i>DHJ</i>	<i>DEHJ</i>	<i>EHJ</i>	<i>DEHJ</i>	Sally	<i>GI</i>	<i>FI</i>	<i>FI</i>	<i>FGI</i>	<p>B1</p> <p>M1</p> <p>A1</p> <p>[3]</p>	<p>Share one or both of <i>A, B</i> (Tariq does any not shared) and Tariq does <i>C</i> or Tariq does all three himself (Sally cannot do <i>A</i> or <i>B</i> on her own, and she cannot do <i>C</i> at all)</p> <p>Sally does <i>I</i> on her own</p> <p>A correct description in which precedences are not violated and project is completed in 18 hours or less</p>				
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